Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

14-17 May 2007
Bagamoyo, Tanzania

CONSERVATION BREEDING SPECIALIST GROUP

WILDLIFE CONSERVATION SOCIETY

TOLEDO ZOO

Kihansi spray toad photos courtesy Dante Fenolio.

A contribution of the Conservation Breeding Specialist Group.

CBSG (IUCN/SSC). 2007. *Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment: Briefing Book*. CBSG: 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124

Additional copies of the *Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment: Briefing Book* can be ordered through the CBSG office: office@cbsg.org. www.cbsg.org

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment

10-17 May 2007
Bagamoyo, Tanzania

Section 1: Introductory Materials
Agenda

Invitation

List of Invitees

Issues Paper for the Proposed Population and Habitat Viability Assessment (PHVA) Workshop for the Preparation of Recovery Plan for the Kihansi Spray Toad (*Nectophrynoides asperginis*). Lower Kihansi Environmental Management Project (LKEMP) IDA Credit No. 3546-TA.

Section 2: CBSG Reference Materials
Introduction to CBSG Workshop Processes

Vortex: A computer Simulation Model for PVA

Vortex Dataforms

Section 3: Kihansi Gorge
Consultancy to Conduct an Environmental Audit of the Lower Kihansi Hydropower Facility. October 2005. Environmental Audit Report-Final Version.

NORPLAN 2002. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Amphibian Studies*. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania

Quinn, C.H., Ndangalasi, H.J., Gerstle, J., Lovett, J.C. 2005. Effect of the Lower Kihansi Hydropower Project and post-project mitigation on wetland vegetation in Kihansi Gorge, Tanzania. Biodiversity and Conservation. 14: 297-308.

Section 4: Kihansi Spray Toad Biology
Channing, A.K., Finlow-Bates, S. 2006. The Biology and Recent History of the Critically Endangered Kihansi Spray Toad *Nectophrynoides asperginis* in Tanzania. *Journal of East African Natural History* 95 (2): 117-138.

Section 5: Chytrid Fungus

Pessier, A.P. Amphibian Chytridiomycosis. *Zoo and Wild Animal Medicine 6th edition*. In Press, WB Saunders and Co.

Skerratt, L.F., Berger, L., Speare, R., Cashins, S., McDonald, K.R., Phillott, A.D., Hines, H.B., Kenyon, N. 2007. Spread of Chytridiomycosis Has Caused the Rapid Global Decline and Extinction of Frogs. *EcoHealth*.

Section 6: Captive Issues

Borek, A. 2007. Kihansi Spray Toad Report No. 14. Wildlife Conservation Society.

DeVoe, R., and Krebs, J. 2007. Developing new amphibian quarantine standards and pre-release screening protocols. *Connect*.

Spray Toad Fact Sheet, Wildlife Conservation Society, Bronx Zoo

Summary of Medical and Surgical Procedures, Kihansi Spray Toad. Wildlife Conservation Society-Bronx Zoo

Lee, S., Zippel, K., Ramos, L., Searle, J. 2006. Captive-breeding programme for the Kihansi spray toad at the Wildlife Conservation Society, Bronx, New York. *International Zoo Yearbook* 40: 241-253.

Mc Aloose, D. 2007. Wildlife Conservation Society Kihansi Spray Toad (*Nectophrynoides asperginis*) Mortality Summary Information.

Zippel, K., R. Lacy, and O. Byers (eds.) 2006. Quarantine Standards from *CBSG/WAZA Amphibian Ex Situ Conservation Planning Workshop Final Report.* IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN 55124, USA. Pages 33-35

Section 7: Reintroductions

IUCN, 2002. Technical Guidelines on the Management of Ex-situ populations for Conservation. As approved at the 14th Meeting of the Programme Committee of Council, Gland, Switzerland, 10 December 2002.

IUCN, 1987. Translocation of living organisms, IUCN position statement. As approved by the 22nd meeting of the IUCN council, Gland, Switzerland, 4 September 1987.

IUCN, 2002. Guidelines for the Placement of Confiscated Animals. Prepared by the IUCN/SSC Re-introduction Specialist Group. IUCN, Gland, Switzerland, and ERWADA, Abu Dhabi, UAE.

IUCN, 1996. IUCN Species Survival Commission guidelines for re-introductions. 41st meeting of the IUCN Council, Gland Switzerland, May 1995.

IUCN, 2000. Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species. 51st Meeting of the IUCN Council, Nairobi, Kenya, May 2000.

Griffiths, R.A., Kuzmin, S.L. Captive Breeding of Amphibians for Conservation.

Griffiths, R.A., McKay, J., Tuberville, T., and Bulhman, K. Reintroductions. *Amphibian Conservation and Action Plan*.

Soorae, P. and F. J. Launay. 2007. Guidelines of the International Union for the Conservation of Nature,(IUCN) for Re-Introductions and their Application to Amphibians. Chapter 24 in: *Conservation and Decline of Amphibians, vol. 8A, Amphibian Biology*, edited by H. Heatwole and J. Wilkinson. Surrey Beatty and Sons, Pty. Ltd., Chipping Norton (*in press*).

Section 8: Other

Krajick, K. 2006. The Lost World of the Kihansi Spray Toad. *Science*. Vol 311 1230-1232.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 1:
Introductory Materials

14-17 May 2007
Bagamoyo, Tanzania

CONSERVATION BREEDING SPECIALIST GROUP

WILDLIFE CONSERVATION SOCIETY

TOLEDO ZOO

LOWER KIHANSI ENVIRONMENTAL MANAGEMENT PROJECT (LKEMP)

NATIONAL WORKSHOP

POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) FOR THE KIHANSI SPRAY TOAD (KST)

DRAFT AGENDA
PARADISE HOTEL, BAGAMOYO
May 14-17, 2007

WORKSHOP OBJECTIVES: generate extinction risk assessments based upon in-depth analysis of information on the life history, population dynamics, ecology, and history of the populations; prepare detailed management and research recommendations and develop a KST Population Recovery Plan.

Foreign guests travelling to Kihansi Gorge should be arriving on May 9[1]. Transportation from the airport to a suitable hotel in Dar es Salaam and later to Kihansi (May 10-13) will be arranged by the LKEMP. Local and Foreign participants who will not travel to Kihansi Gorge are expected to arrive at the venue (travelling from Dar es Salaam to Bagamoyo) on the 13th.

DAY ONE, MONDAY 14TH MAY 2007 **SESSESION 1: Chairperson: Permanent Secretary - VPO**		
TIME	**ACTIVITY**	**RESPONSIBLE PERSON/PARTY**
7:00-8:00am	**BREAKFAST**	ALL
8:00– 8:30 am	Arrival of participants, registration and announcements	Secretariat (VPO & MNRT)
8.30 – 9.00 am	Briefing Remarks	Mr. B. Baya, Ag DG NEMC
9:00 – 9:20 am	Introduction and Welcome Remarks	Permanent Secretary (PS) – Vice President's Office
9:20 – 9:30am	Statement by the World Bank speaking on behalf of the Donor Community	Country Director, World Bank
9:30 – 9:40am	**OFFICIAL OPENING SPEECH**	Hon.Prof. Mwandosya (MP) Minister of State (Environment) - VPO
9:40 – 9:45am	Vote of Thanks	Mr. Salahe Pamba - PS – Ministry of Natural Resources and Tourism
	participant introductions	
9:45am – 10:15am	Keynote Address: Conservation Breeding Specialist Group and the Kihansi Spray	Ms. Yolan Friedmann, CBSG

[1] We are planning to organize an optional field trip to Kihansi Gorge via the Mikumi National Park in Morogoro probably from May 10-12, 2007 This is intended to give key participants first hand knowledge of the Kihansi Gorge Spray wetlands

	Toad (KST) PHVA workshop process	
10:15am – 10:45am	Keynote Address: Using Simulation Models for PVA and PHVA	Ms. Kerryn Morrison, CBSG
10:45am – 11:00am	KST natural History and the LKEMP interventions in-situ	Prof. Kim Howell & Dr. W. Sarunday
	Population trend and Status of Captive populations at the Bronx and Toledo zoos	Mr. Andy Odum, Toledo Zoo
11:00 – 11:30	GROUP PHOTO and TEA/Coffee Break	ALL
11:30am – 12:00pm	Chytrid Fungus and the and the Kihansi Gorge	Dr. Che Weldon, North-West University
12:00pm – 01:00pm	Reintroduction science	Dr. Pritpal Soorae, Reintroduction Specialist Group
01:00– 1:30pm	**LUNCH**	ALL
SESSION 2	**Chairperson: Director of Wildlife**	
01:30– 02:00pm	Biosecurity, hygiene, ex-situ facilities for the Kihansi captive breeding center	Mr. Gerry Marantelli, Amphibian Research Centre
OPEN	Preliminary development of the KST baseline model, Discussion of goals, and Identification of outstanding issues in baseline model	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
OPEN	Identify and theme key issues	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
OPEN	Working group instructions and formation	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
-6:00pm		
6:00-7:00pm	**DINNER**	ALL
evening	open	

Tasks to be completed over the following 2.5 days

Task 1a: Amplify the issues within your group's topic to ensure they are clear and understandable. This is not the time to develop solutions or actions or research projects for the problems. This will be done in later steps in the process.

Task 1b: Consolidate, where appropriate, the ideas generated in the first step. Write a one or two sentence 'problem statement' for each issue. Retain a list of the individual issues under the problem statement.

Task 1c: Prioritize problem statements.

Task 2: Data assembly and analysis. Begin an exhaustive process to determine the facts and assumptions that are pertinent to your group's issues. What do we *know*? What do we *assume* we know? How do we justify our assumptions? What do we *need* to know?

Task 3: Brainstorm, and then prioritize, potential solutions for each high priority problem.

Task 4: Translate potential solutions into population model input data.

Task 5: Develop and prioritize recommendations for implementation of preferred solutions

Task 6: Prepare detailed action steps for each top priority recommendation and Develop a KST Recovery Plan.

DAY TWO, TUESDAY 15TH MAY 2007 **SESSESION 3: Chairperson: CBSG**		
TIME	**ACTIVITY**	**RESPONSIBLE PERSON/PARTY**
7:00-8:00am	**BREAKFAST**	ALL
8:00-10:00am	Working Group Session: **Task 1**: Amplification of issues and problem statement development	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
10:00-10:30am	Plenary Session: Working group reports	
10:30-10:45am	**COFFEE/TEA BREAK**	ALL
10:45-12:30pm	Working Group Session: **Task 2**: Data assembly and analysis	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
12:30-1:00pm	Plenary Session: Working group reports	
1:00– 1:30pm	**LUNCH**	ALL
1:30-3:00pm	Working Group Session: **Task 3**: Brainstorming of potential solutions	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
3:00-3:30pm	Plenary Session: Working group reports	
3:30-3:45pm	**COFFEE/TEA BREAK**	ALL
3:45-5:30pm	Working Group Session: **Task 4**: Translation of potential solutions into population model input data	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
5:30-6:00pm	Plenary Session: Working group reports	Group Chairpersons
6:00-7:00pm	**DINNER**	ALL
evening	open	
DAY THREE, WEDNESDAY MAY 16TH MAY 2007 **SESSESION 4: Chairperson: CBSG**		
TIME	**ACTIVITY**	**RESPONSIBLE PERSON/PARTY**

7:00-8:00am	**BREAKFAST**	ALL
8:00-10:30am	Working Group Session: **Task 5**: Revision of solutions based on model results, and development of recommendations for implementation of preferred solutions	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
10:30-10:45am	**COFFEE/TEA BREAK**	ALL
10:45-12:30pm	continue **Task 5**	
12:30-1:00pm	Plenary Session: Working group reports on recommendations and presentation of revised population models	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
01:00– 1:30pm	**LUNCH**	ALL
1:30-3:30pm	Working Group Session: **Task 6**: Revision of priority recommendations, begin development of KST recovery plan	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
3:30-3:45pm	**COFFEE/TEA BREAK**	ALL
3:45-5:30pm	continue **Task 6**	
5:30-6:00pm	Plenary Session: Workshop recommendation prioritization	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
6:00-7:00pm	**DINNER**	ALL
evening	open	
DAY FOUR, THURSDAY 17TH MAY 2007 **SESSESION 5: Chairperson: CBSG**		
TIME	**ACTIVITY**	**RESPONSIBLE PERSON/PARTY**
7:00-8:00am	**BREAKFAST**	ALL
8:00-10:30am	continue **Task 6:** Continued KST recovery plan development, finalization of working group reports	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
10:30-10:45am	**COFFEE/TEA BREAK**	ALL
10:45-12:30pm	continue **Task 6**	
12:30-1:00pm	Plenary Session: Plans and strategies for further work by PHVA participants and partners	Facilitators Ms. Yolan Friedmann and the IUCN/CBSG team
01:00– 1:30pm	**LUNCH**	ALL
	OFFICIAL WORKSHOP CLOSING	
1:30 – 1:40pm	Welcoming Minister, Minister of Natural Resources and Tourism(MNRT)	Chairperson
1.40 – 2.00pm	Closing Statement	Minister - MNRT
DAY FIVE, FRIDAY 18TH MAY 2007		
DEPARTURE TO DAR ES SALAAM AND OVERSEAS		

NATIONAL ENVIRONMENT MANAGEMENT COUNCIL (NEMC)

LOWER KIHANSI ENVIRONMENTAL MANAGEMENT PROJECT (LKEMP)
NATIONAL WORKSHOP

POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)
FOR THE KIHANSI SPRAY TOAD

PARADISE HOTEL, BAGAMOYO
MAY 14-17, 2007

Dear Colleague,

You are invited to attend the Kihansi spray toad Population and Habitat Viability Assessment (PHVA) to be held in Bagamoyo, Tanzania from 14-17 May 2007.

As you know, we are in the midst of an amphibian extinction crisis. A third of the world's 6,000 amphibian species are threatened with extinction. The status of many more is unknown but believed to be imperiled, bringing the percentage of threatened species potentially as high as 50%. This is significantly more than any other group of organisms: by comparison, 12% of bird species and 23% of mammal species are threatened. Recent amphibian extinctions exceed 120 species and one entire family is already lost. The IUCN has urged that "All Critically Endangered and Extinct in the Wild taxa should be subject to *ex situ* management to ensure recovery of wild populations." (IUCN, 2002). Comparable calls to action are included in the Global Amphibian Assessment and other IUCN documents. Without immediate captive management as a stopgap component of an integrated conservation effort, hundreds of species will become extinct.

The Kihansi spray toad (*Nectophrynoides asperginis*) appears to be one such species on the brink of extinction. Endemic to 2.0 hectares of spray zone in the Kihansi Gorge in south-central Tanzania, its habitat was decimated by dam construction from 1996-2000 and amphibian chytrid fungus in ~2003. Wild populations plummeted from tens of thousands to a few per year in a couple months. Although an *ex situ* assurance population of 500 animals was established in 2000, numbers fell steadily for 4 years reaching ~15% of the original size. The population size has been rising since 2005 and is now approaching initial levels.

With *in situ* and *ex situ* programs facing continued challenges, a recovery strategy is urgently needed. This PHVA workshop is designed to generate extinction risk assessments based upon in-depth analysis of information on the life history, population dynamics, ecology, and history of the populations, and to develop detailed management and research recommendations. We hope you will participate in this important effort. You are also invited to join us for a field trip to the Kihansi Gorge 10 -12 May.

As space is limited, we ask that you let us know immediately if you plan to attend the workshop and/or gorge trip. **Please register by contacting Kevin Zippel at KevinZ@AmphibianArk.org.** We have a limited budget for this workshop, and we hope that support will be available from your institution. However, if you require financial assistance from the organizers please contact us immediately. Please forward to us the contact information of anyone else you think needs to be invited to this meeting. We are particularly interested in experts on this species, but also experts in amphibian biology and reintroductions in general.

In preparation for this workshop, we also ask that you send us all data, papers (published or not), and any other information on this species. This information will be assembled into a Briefing Book, which will be provided to all participants prior to their arrival, and pertinent life history data will be extracted for use in computer modeling of population dynamics. Please send this information to the organizers by 15 April 2007. Please, do not let your valuable data (or other data about which you are aware) be omitted from the important analyses and deliberations to occur at the meeting. Thank you for your prompt reply, Wilfred Sarunday and Kevin Zippel

KC Zippel

POPULATION AND HABITAT ASSESSMENT WORKSHOP FOR THE KIHANSI SPRAY TOAD: PARADISE HOLIDAY RESORT - BAGAMOYO, MAY 14 – 17, 2007

DRAFT LIST OF POTENTIAL PARTICIPANTS

SUMMARY

- Tanzania
- Bronx and Toledo Zoo
- CBSG
- Other experts

1. From Tanzania:

- Ministry of Natural Resources and Tourism
- Vice-President's Office
- Ministry of Energy and Minerals
- Ministry of Water
- University of Dar es Salaam
- Sokoine University of Agriculture
- Mweka Wildlife College
- Tanzania Wildlife Research Institute
- Wildlife Conservation Society of Tanzania
- Eastern Arc Mountain Endowment Fund
- Eastern Arc Conservation and Management Project -
- LKEMP
- Representative – Mufindi District Council
- Representative – Kilolo District Council
- Representative – Kilombero District Council

2. From the US Captive Breeding Zoos

From WCS/Bronx zoo:

1. Jennifer Pramuk
2. Dee McAloose
3. Alyssa Borek

From Toledo Zoo:

1. Andy Odum
2. Tim Herman
3. Wynona Shellabarger

3. From World Bank:

1. Ladisy Chengula
2. Bill Newmark
3. Jane Kibbassa

4. From the IUCN Conservation Breeding Specialist Group (CBSG):

1. Kevin Zippel
2. Kerryn Morrison
3. Yolan Friedmann

5. Other Experts/scientists who have worked with KST issues

1. Che Weldon
2. Peter Hawkes
3. John Gerstle
4. James Gibbs

6. International experts with relevant experience

1. Pritpal Soorae
2. Gerry Marantelli
3. Allan Pessier

THE UNITED REPUBLIC OF TANZANIA

VICE PRESIDENT'S OFFICE

LOWER KIHANSI ENVIRONMENTAL MANAGEMENT PROJECT (LKEMP)

IDA CREDIT No. 3546 – TA

ISSUES PAPER FOR THE PROPOSED POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) WORKSHOP FOR THE PREPARATION OF RECOVERY PLAN FOR THE KIHANSI SPRAY TOAD (*NECTOPHRYNOIDES ASPERGINIS*)

LKEMP
April, 2007

LOWER KIHANSI ENVIRONMENTAL MANAGEMENT PROJECT (LKEMP): THE FUTURE OF NECTOPHRYNOIDES ASPERGINIS, THE KIHANSI SPRAY TOAD (ANURA: BUFONIDAE)

Original KST habitat at Kihansi Gorge, Tanzania

KST in captivity at the Toledo zoo, USA

ISSUES PAPER

Discussion topics planned for the LKEMP PHVA workshop for the Kihansi spray toad, 13–18 May 2007

Included Acronyms: CBSG (Conservation Breeding Specialist Group); IUCN (World Conservation Union); KST (Kihansi spray toads); LKEMP (Lower Kihansi Environmental Management Project); PHVA (Population and Habitat Viability Assessment); SVL (snout–vent length); VPO (Vice-President's Office).

INTRODUCTION:

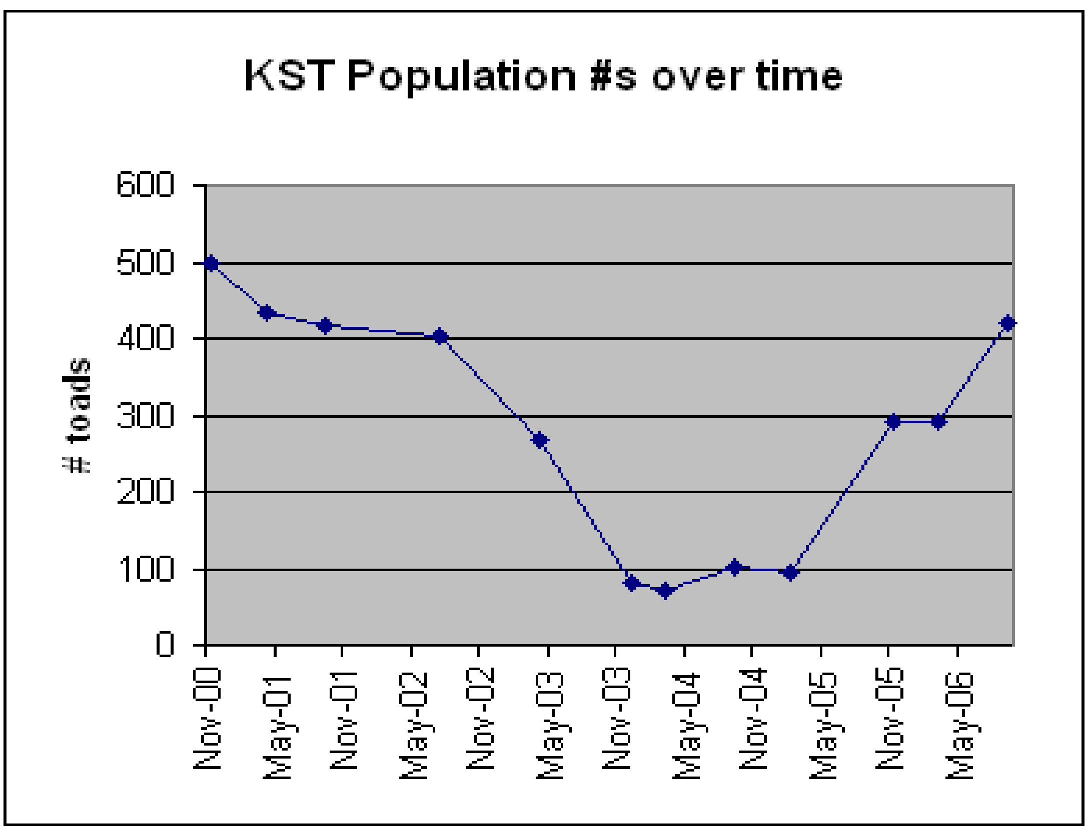
The purpose of this paper is to provide a brief background on the KST and identify issues that will be raised at the PHVA workshop in Tanzania in May 2007. The workshop will consist of approximately 45-55 individuals who will assemble in Bagamoyo for four days to discuss crucial issues relating to future in-situ and ex-situ propagation success of this species as well as understanding the requirements for potential future reintroduction of KSTs to their native habitat. Invitees hail from the World Bank, South Africa and other international institutions; however, most (36) participants are from Tanzania and represent several in-country governmental agencies, universities, and wildlife groups. All participants have expertise on one or more key aspects of KST management, population genetics, in and ex situ conservation, natural history, epidemiology, and/or other relevant conservation areas. Participation of both in-country and international scientists and other individuals and their continued collaboration will be crucial for ensuring the perpetual survival of the KST.

BACKGROUND:

The World is in the midst of an amphibian extinction crisis. A third of the world's 6,000 amphibian species are threatened with extinction. The status of many more is unknown but believed to be imperiled, bringing the percentage of threatened species potentially as high as 50%. This is significantly more than any other group of organisms: by comparison, 12% of bird species and 23% of mammal species are threatened. Recent amphibian extinctions exceed 120 species and one entire family is already lost. The IUCN has urged that "All Critically Endangered and Extinct in the Wild taxa should be subject to *ex situ* management to ensure recovery of wild populations." (IUCN, 2002). Comparable calls to action are included in the Global Amphibian Assessment and other IUCN documents. Without immediate captive management as a stopgap component of an integrated conservation effort, hundreds of species will become extinct.

The Kihansi spray toad (*Nectophrynoides asperginis*) appears to be one such species on the brink of extinction. Endemic to 2.0 hectares of spray zone in the Kihansi Gorge in south-central Tanzania, its habitat was decimated by dam construction from 1996-2000 and amphibian chytrid fungus in ~2003. Wild populations plummeted from tens of thousands to a few per year in a couple months. Although an *ex situ* assurance population of 500 animals was established in 2000, numbers fell steadily for 4 years reaching ~15% of the original size. The population size has been rising since 2005, and today, populations of this toad are thought to be limited to the two remaining captive zoo populations, currently totaling 460 individuals (see the population dynamic graph below).

As of 12 February 2007, the current census at the Bronz zoo (the WCS) is comprised of a sex distribution of 43.51.185 (**n = 279**) and that of Toledo Zoo is comprised of 62.62.57 (**n = 181**). It is important to note that animals mixed between generations, individual identities and generation no longer identifiable for discrete census calculations.



Despite the fact that the KST was first taxonomically described only nine years ago (Poynton et al., 1998), it is listed as Critically Endangered (CR) by the IUCN and may be extinct in the wild (Krajick, 2006). This bufonid is notable as it bears live young—a highly unusual reproductive strategy among anurans. The females retain their fertilized eggs and larvae in their oviducts until the toadlets are born as miniature, grey versions of the adults (Channing et al., 2006). Historically, this species was abundant, with a population of approximately 17,000 individuals (Lee et al., 2006). In 1999 the population began to decline as the result of several causes, including the disappearance of their waterfall spray zone habitat resulting from the construction of a hydroelectric dam and confirmed presence of chytridiomycosis (chytrid), a newly discovered fungal pathogen that quickly can kill entire populations of frogs. The limited distribution and low fecundity of this species, coupled with chytrid infection and extreme habitat alteration, have culminated in its precipitous decline.

In 2000, 499 adult KST were transported from Tanzania to the United States with the hope of propagating stable captive assurance colonies. These founders formed an ex situ population that was divided among several zoos in the U.S., among them being the two institutions where they remain today, the Toledo Zoo and Bronx Zoo.

The last two sighting of the Kihansi spray toad in the wild was in May of 2005 when a biologist claimed to see one individual (Krajick, 2006). Despite several surveys since that time there have been no confirmed sightings. As a result, several scientists suspect that the KST may be hibernating or extinct in the wild. However, habitat studies conducted so far indicates that with the functioning of the primary and secondary sprinkling system the original vegetation, other amphibian species and insect communities are slowly returning to pre-diversion state.

With *in situ* and *ex situ* programs in such a precarious state, a KST recovery plan and management strategy is urgently needed. This PHVA workshop is designed to generate extinction risk assessments based upon in-depth analysis of information on the life history, population dynamics, ecology, and history of the populations, and to develop a KST Recovery Plan.

LKEMP PHVA WORKSHOP ISSUES:

The government of Tanzania through the VPO and the LKEMP intends to apply a portion of the World Bank/IDA credit/ grant to organize a Population and Habitat Viability Assessment (PHVA) workshop at Bagamoyo Tanzania from 13-18 May 2007 with a view to developing a comprehensive KST recovery plan. The PHVA is a collaborative effort that will involve a wide range of stakeholders including the World Bank, the CBSG/AArk, and the AZA, researchers, scientists, and animal keepers and others with expertise on the conservation and management of the KST. While convened, participants will discuss measures necessary for continued ex situ propagation success as well as the potential future reintroduction of this species into its native habitat. For example, discussions are urgently needed to determine whether or not any individuals survive in the wild, and if they are whether or not chytridiomycosis is still present in any remaining individuals. If no remaining KST are found, the presence of chytrid in other sympatric anuran species must be determined.

Issues to be discussed at the workshop will include:

1. **Ex - situ management**

- the science of ex situ propagation
- translating ex situ science from the US into developing an in-country ex situ facility
- AArk recommended biosecurity measures
- unique challenges of an in-country ex situ propagation program
- guidelines for training in-country propagation teams
- population genetics as it pertains to ensuring heterozygosity

2. **Re-introductions**

- obstacles of reintroduction and its long term viability
- IUCN guidelines for reintroduction
- socio-economic and legal requirements for reintroduction
- habitat assessment in the Kihansi Gorge
- implications of the artificial spray zone
- potential vs. real threats of chytridiomycosis in the Kihansi Gorge
- scientific advancements in the effective treatment of chytrid
- availability of suitable release stock
- steps necessary for potential reintroduction
- developing a timeline and budget to reach ultimate goal of reintroduction

3. **Capacity Building for maintaining captive populations of critically endangered species in Tanzania**

    - Skills, competencies and training requirements for effective captive husbandry in Tanzania
    - Availability of training opportunities abroad
    - guidelines for training in-country propagation teams
    - Mechanisms for linking in-situ and ex-situ processes (both in Tanzania and the US)

4. **Recovery Plan for the KST**

    - KST information: description, distribution, habitat, current conservation status, life history and Ecology
    - Previous recovery actions – pre diversion and post commissioning autecological surveys, research and monitoring, captive breeding, genetic studies at the zoos, etc.

- ❖ Ability of KST to recover and other species management issues, e.g. the presence of Chytrid fungus ***Batrachochytrium***, invasion by weed plant species in the spray wetlands, availability of food items at the Gorge, water quality and quantity;
- ❖ Conservation requirements of the KST across its known range in Tanzania
- ❖ Actions to be taken to ensure long-term viability of the KST in Tanzania
- ❖ Institutional arrangements to implement actions included in the recovery plan
- ❖ Budgetary and other inputs necessary for the attainments of the recovery plan's objectives

The government of Tanzania, the World Bank, and AZA institutions are working closely to ensure the survival of the KST in the wild. The greatest threat to the survival of the KST is unsuitable habitat resulting from irreversible habitat alteration and introduction of chytrid fungus. The primary goal of this workshop will be to devise a Recovery Plan for this species via collaborative effort and sharing current knowledge of husbandry techniques, bio-security, reintroduction science, and population genetics. The ultimate goals will be to prioritize objectives for continued captive propagation, to study and understand the probability of future reintroductions, and to devise a realistic timeline and budget for meeting these goals.

LITERATURE CITED:

1. Channing, A., K. S. Finlow-Bates, S. E. Haarklau, P. G. Hawkes, 2006. The biology and recent history of the Kihansi spray toad Nectophrynoides asperginis in Tanzania. Journal of East African Natural History. 95:117–138.
2. Krajick, K. 2006. The lost world of the Kihansi toad. Science. 311:1230–1232.
3. Lee, S., K. Zippel, L. Ramos, and J. Searle. 2006. Captive breeding programme for the Kihansi spray toad at the Wildlife Conservation Society, Bronx, New York. International Zoo Yearbook. 40:241–253,
4. Poynton, J. C., K. M. Howell, B. T. Clarke, and J. C. Lovett. 1998. A critically endangered new species of Nectophrynoides (Anura: Bufonidae) from the Kihansi Gorge, Udzungwa Mountains, Tanzania. African Journal of Herpetology 47:59–67.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 2:
CBSG Reference Materials

14-17 May 2007
Bagamoyo, Tanzania

CBSG Workshop Process

The problems facing wildlife populations around the globe are so urgent and varied that it is vital to apply the limited resources available for intensive management as efficiently and effectively as possible. Despite our recognition of this need, there is a lack of generally accepted tools to evaluate and integrate the interaction of biological, physical, and social factors on the population dynamics of threatened species and populations. Consequently, there is a pressing need for methods and processes to characterize the risk of habitat loss and species extinction, on the possible impacts of future events, on the effects of management interventions, and on how to develop and sustain learning-based cross-institutional management programs.

CBSG has over a decade of experience in developing, testing and applying a series of scientifically based tools and processes to assist risk characterization and species management decision making. These tools - based on small population and conservation biology (biological and physical factors), human demography, and the dynamics of social learning - are used in intensive, problem-solving workshops to produce realistic and achievable recommendations for both in situ and ex situ population management.

Our Workshop processes provide an objective environment, expert knowledge, and a neutral facilitation process that supports sharing of available information across institutions and stakeholder groups, reaching agreement on the issues and available information, and then making useful and practical management recommendations for the taxon and habitat system under consideration. The process has been remarkably successful in unearthing and integrating previously unpublished information for the decision making process. Their proven heuristic value and constant refinement and expansion have made CBSG workshop processes one of the most imaginative and productive organizing forces for species conservation today.

Each CBSG workshop is a consensus-building process in which all interested stakeholders participate. Participants are encouraged to leave any personal agenda at the door to focus on a common goal: preventing the extinction of the species or group of species under review. These processes allow for the extraction of knowledge from expert participants, recognizing that it is likely that 80% of the information about species usually is in managers', researchers', and local peoples' heads and may never be published. Workshop processes facilitate the validation of each person's experience and perspective. In many cases, people have been working on the same species for years but may never have met face-to-face to discuss pertinent conservation issues.

Frequently, local management agencies, external consultants, and local experts have identified management actions. However, an isolated narrow professional approach which focuses primarily on the perceived biological problems seems to have little effect on the needed political and social changes (social learning) for collaboration, effective management and conservation of habitat fragments or protected areas and their species components. CBSG workshops are organized to bring together the full range of groups with a strong interest in conserving and managing the species in its habitat and those effected by the consequences of such management. One goal in all workshops is to reach a common understanding of the state of scientific knowledge available and its possible application to the decision-making process and needed management actions. We have found that the decision-making driven workshop process with risk characterization tools, stochastic simulation modeling, scenario testing, and deliberation among stakeholders is a powerful tool for extracting, assembling, and exploring information. This process encourages the development of a shared understanding across wide boundaries of training and expertise. These tools also support building of working agreements and instilling local ownership of the problems, the decisions required, and their management during the workshop process. As participants appreciate the complexity of the problems as a group, they take more ownership of the process as well as the ultimate recommendations made to achieve workable solutions. This is essential if the management recommendations generated by the workshops are to succeed. Finally, CBSG acts as an impartial, knowledge-based facilitator, not as a consultant, in these processes. The recommendations are made by and the resultant document is written and "owned" entirely by the participants. Rapid turnaround is key - generally, a rough draft document is generated by the end of each workshop and a second draft is in the hands of the participants within several weeks for further review. The participants' comments are then incorporated, and the final report is distributed 2-4 months after the workshop.

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VORTEX: A Computer Simulation Model for Population Viability Analysis

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Abstract

Population Viability Analysis (PVA) is the estimation of extinction probabilities by analyses that incorporate identifiable threats to population survival into models of the extinction process. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity. Computer simulation modelling provides a tool for exploring the viability of populations subjected to many complex, interacting deterministic and random processes. One such simulation model, VORTEX, has been used extensively by the Captive Breeding Specialist Group (Species Survival Commission, IUCN), by wildlife agencies, and by university classes. The algorithms, structure, assumptions and applications of VORTEX are described in this paper.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, to determine the number of progeny produced by each female each year, and to determine which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Fecundity is assumed to be independent of age after an animal reaches reproductive age. Mortality rates are specified for each pre-reproductive age–sex class and for reproductive-age animals. Inbreeding depression is modelled as a decrease in viability in inbred animals.

The user has the option of modelling density dependence in reproductive rates. As a simple model of density dependence in survival, a carrying capacity is imposed by a probabilistic truncation of each age class if the population size exceeds the specified carrying capacity. VORTEX can model linear trends in the carrying capacity. VORTEX models environmental variation by sampling birth rates, death rates, and the carrying capacity from binomial or normal distributions. Catastrophes are modelled as sporadic random events that reduce survival and reproduction for one year. VORTEX also allows the user to supplement or harvest the population, and multiple subpopulations can be tracked, with user-specified migration among the units.

VORTEX outputs summary statistics on population growth rates, the probability of population extinction, the time to extinction, and the mean size and genetic variation in extant populations.

VORTEX necessarily makes many assumptions. The model it incorporates is most applicable to species with low fecundity and long lifespans, such as mammals, birds and reptiles. It integrates the interacting effects of many of the deterministic and stochastic processes that have an impact on the viability of small populations, providing opportunity for more complete analysis than is possible by other techniques. PVA by simulation modelling is an important tool for identifying populations at risk of extinction, determining the urgency of action, and evaluating options for management.

Introduction

Many wildlife populations that were once widespread, numerous, and occupying contiguous habitat, have been reduced to one or more small, isolated populations. The causes of the original decline are often obvious, deterministic forces, such as over-harvesting,

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habitat destruction, and competition or predation from invasive introduced species. Even if the original causes of decline are removed, a small isolated population is vulnerable to additional forces, intrinsic to the dynamics of small populations, which may drive the population to extinction (Shaffer 1981; Soulé 1987; Clark and Seebeck 1990). Of particular impact on small populations are stochastic processes. With the exception of aging, virtually all events in the life of an organism are stochastic. Mating, reproduction, gene transmission between generations, migration, disease and predation can be described by probability distributions, with individual occurrences being sampled from these distributions. Small samples display high variance around the mean, so the fates of small wildlife populations are often determined more by random chance than by the mean birth and death rates that reflect adaptations to their environment.

Although many processes affecting small populations are intrinsically indeterminate, the average long-term fate of a population and the variance around the expectation can be studied with computer simulation models. The use of simulation modelling, often in conjunction with other techniques, to explore the dynamics of small populations has been termed Population Viability Analysis (PVA). PVA has been increasingly used to help guide management of threatened species. The Resource Assessment Commission of Australia (1991) recently recommended that 'estimates of the size of viable populations and the risks of extinction under multiple-use forestry practices be an essential part of conservation planning'. Lindenmayer *et al.* (1993) describe the use of computer modelling for PVA, and discuss the strengths and weaknesses of the approach as a tool for wildlife management.

In this paper, I present the PVA program VORTEX and describe its structure, assumptions and capabilities. VORTEX is perhaps the most widely used PVA simulation program, and there are numerous examples of its application in Australia, the United States of America and elsewhere.

The Dynamics of Small Populations

The stochastic processes that have an impact on populations have been usefully categorised into demographic stochasticity, environmental variation, catastrophic events and genetic drift (Shaffer 1981). Demographic stochasticity is the random fluctuation in the observed birth rate, death rate and sex ratio of a population even if the probabilities of birth and death remain constant. On the assumption that births and deaths and sex determination are stochastic sampling processes, the annual variations in numbers that are born, die, and are of each sex can be specified from statistical theory and would follow binomial distributions. Such demographic stochasticity will be important to population viability only in populations that are smaller than a few tens of animals (Goodman 1987), in which cases the annual frequencies of birth and death events and the sex ratios can deviate far from the means. The distribution of annual adult survival rates observed in the remnant population of whooping cranes (*Grus americana*) (Mirande *et al.* 1993) is shown in Fig. 1. The innermost curve approximates the binomial distribution that describes the demographic stochasticity expected when the probability of survival is 92·7% (mean of 45 non-outlier years).

Environmental variation is the fluctuation in the probabilities of birth and death that results from fluctuations in the environment. Weather, the prevalence of enzootic disease, the abundances of prey and predators, and the availability of nest sites or other required microhabitats can all vary, randomly or cyclically, over time. The second narrowest curve on Fig. 1 shows a normal distribution that statistically fits the observed frequency histogram of crane survival in non-outlier years. The difference between this curve and the narrower distribution describing demographic variation must be accounted for by environmental variation in the probability of adult survival.

Catastrophic variation is the extreme of environmental variation, but for both methodological and conceptual reasons rare catastrophic events are analysed separately from the more typical annual or seasonal fluctuations. Catastrophes such as epidemic disease,

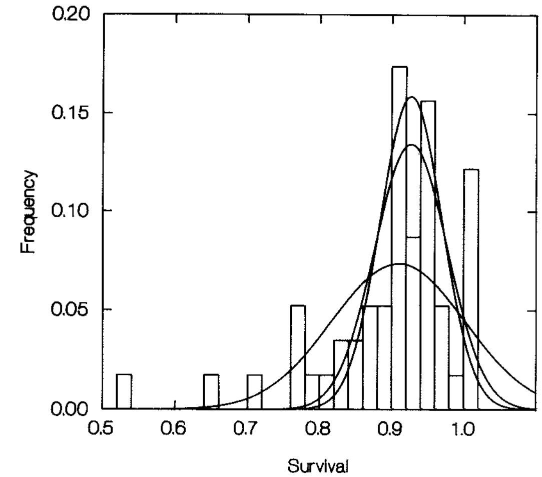

Fig. 1. Frequency histogram of the proportion of whooping cranes surviving each year, 1938–90. The broadest curve is the normal distribution that most closely fits the overall histogram. Statistically, this curve fits the data poorly. The second highest and second broadest curve is the normal distribution that most closely fits the histogram, excluding the five leftmost bars (7 outlier 'catastrophe' years). The narrowest and tallest curve is the normal approximation to the binomial distribution expected from demographic stochasticity. The difference between the tallest and second tallest curves is the variation in annual survival due to environmental variation.

hurricanes, large-scale fires, and floods are outliers in the distribution of environmental variation (e.g. five leftmost bars on Fig. 1). As a result, they have quantitatively and sometimes qualitatively different impacts on wildlife populations. (A forest fire is not just a very hot day.) Such events often precipitate the final decline to extinction (Simberloff 1986, 1988). For example, one of two populations of whooping crane was decimated by a hurricane in 1940 and soon after went extinct (Doughty 1989). The only remaining population of the black-footed ferret (*Mustela nigripes*) was being eliminated by an outbreak of distemper when the last 18 ferrets were captured (Clark 1989).

Genetic drift is the cumulative and non-adaptive fluctuation in allele frequencies resulting from the random sampling of genes in each generation. This can impede the recovery or accelerate the decline of wildlife populations for several reasons (Lacy 1993). Inbreeding, not strictly a component of genetic drift but correlated with it in small populations, has been documented to cause loss of fitness in a wide variety of species, including virtually all sexually reproducing animals in which the effects of inbreeding have been carefully studied (Wright 1977; Falconer 1981; O'Brien and Evermann 1988; Ralls *et al.* 1988; Lacy *et al.* 1993). Even if the immediate loss of fitness of inbred individuals is not large, the loss of genetic variation that results from genetic drift may reduce the ability of a population to adapt to future changes in the environment (Fisher 1958; Robertson 1960; Selander 1983).

Thus, the effects of genetic drift and consequent loss of genetic variation in individuals and populations have a negative impact on demographic rates and increase susceptibility to environmental perturbations and catastrophes. Reduced population growth and greater fluctuations in numbers in turn accelerate genetic drift (Crow and Kimura 1970). These synergistic destabilising effects of stochastic process on small populations of wildlife have been described as an 'extinction vortex' (Gilpin and Soulé 1986). The size below which a population is likely to be drawn into an extinction vortex can be considered a 'minimum viable population' (MVP) (Seal and Lacy 1989), although Shaffer (1981) first defined a MVP more stringently as a population that has a 99% probability of persistence for 1000 years. The estimation of MVPs or, more generally, the investigation of the probability of extinction constitutes PVA (Gilpin and Soulé 1986; Gilpin 1989; Shaffer 1990).

Methods for Analysing Population Viability

An understanding of the multiple, interacting forces that contribute to extinction vortices is a prerequisite for the study of extinction–recolonisation dynamics in natural populations inhabiting patchy environments (Gilpin 1987), the management of small populations (Clark and Seebeck 1990), and the conservation of threatened wildlife (Shaffer 1981, 1990; Soulé 1987; Mace and Lande 1991). Because demographic and genetic processes in small populations are inherently unpredictable, the expected fates of wildlife populations can be described in terms of probability distributions of population size, time to extinction, and genetic variation. These distributions can be obtained in any of three ways: from analytical models, from empirical observation of the fates of populations of varying size, or from simulation models.

As the processes determining the dynamics of populations are multiple and complex, there are few analytical formulae for describing the probability distributions (e.g. Goodman 1987; Lande 1988; Burgmann and Gerard 1990). These models have incorporated only few of the threatening processes. No analytical model exists, for example, to describe the combined effect of demographic stochasticity and loss of genetic variation on the probability of population persistence.

A few studies of wildlife populations have provided empirical data on the relationship between population size and probability of extinction (e.g. Belovsky 1987; Berger 1990; Thomas 1990), but presently only order-of-magnitude estimates can be provided for MVPs of vertebrates (Shaffer 1987). Threatened species are, by their rarity, unavailable and inappropriate for the experimental manipulation of population sizes and long-term monitoring of undisturbed fates that would be necessary for precise empirical measurement of MVPs. Retrospective analyses will be possible in some cases, but the function relating extinction probability to population size will differ among species, localities and times (Lindenmayer *et al.* 1993).

Modelling the Dynamics of Small Populations

Because of the lack of adequate empirical data or theoretical and analytical models to allow prediction of the dynamics of populations of threatened species, various biologists have turned to Monte Carlo computer simulation techniques for PVA. By randomly sampling from defined probability distributions, computer programs can simulate the multiple, interacting events that occur during the lives of organisms and that cumulatively determine the fates of populations. The focus is on detailed and explicit modelling of the forces impinging on a given population, place, and time of interest, rather than on delineation of rules (which may not exist) that apply generally to most wildlife populations. Computer programs available to PVA include SPGPC (Grier 1980*a*, 1980*b*), GAPPS (Harris *et al.* 1986), RAMAS (Ferson and Akçakaya 1989; Akçakaya and Ferson 1990; Ferson 1990), FORPOP (Possingham *et al.* 1991), ALEX (Possingham *et al.* 1992), and SIMPOP (Lacy *et al.* 1989; Lacy and Clark 1990) and its descendant VORTEX.

SIMPOP was developed in 1989 by converting the algorithms of the program SPGPC (written by James W. Grier of North Dakota State University) from BASIC to the C programming language. SIMPOP was used first in a PVA workshop organised by the Species Survival Commission's Captive Breeding Specialist Group (IUCN), the United States Fish and Wildlife Service, and the Puerto Rico Department of Natural Resources to assist in planning and assessing recovery efforts for the Puerto Rican crested toad (*Peltophryne lemur*). SIMPOP was subsequently used in PVA modelling of other species threatened with extinction, undergoing modification with each application to allow incorporation of additional threatening processes. The simulation program was renamed VORTEX (in reference to the extinction vortex) when the capability of modelling genetic processes was implemented in 1989. In 1990, a version allowing modelling of multiple populations was briefly named VORTICES. The only version still supported, with all capabilities of each previous version, is VORTEX Version 5.1.

VORTEX has been used in PVA to help guide conservation and management of many species, including the Puerto Rican parrot (*Amazona vittata*) (Lacy *et al.* 1989), the Javan rhinoceros (*Rhinoceros sondaicus*) (Seal and Foose 1989), the Florida panther (*Felis concolor coryi*) (Seal and Lacy 1989), the eastern barred bandicoot (*Perameles gunnii*) (Lacy and Clark 1990; Maguire *et al.* 1990), the lion tamarins (*Leontopithecus rosalia* ssp.) (Seal *et al.* 1990), the brush-tailed rock-wallaby (*Petrogale penicillata penicillata*) (Hill 1991), the mountain pygmy-possum (*Burramys parvus*), Leadbeater's possum (*Gymnobelideus leadbeateri*), the long-footed potoroo (*Potorous longipes*), the orange-bellied parrot (*Neophema chrysogaster*) and the helmeted honeyeater (*Lichenostomus melanops cassidix*) (Clark *et al.* 1991), the whooping crane (*Grus americana*) (Mirande *et al.* 1993), the Tana River crested mangabey (*Cercocebus galeritus galeritus*) and the Tana River red colobus (*Colobus badius rufomitratus*) (Seal *et al.* 1991), and the black rhinoceros (*Diceros bicornis*) (Foose *et al.* 1992). In some of these PVAs, modelling with VORTEX has made clear the insufficiency of past management plans to secure the future of the species, and alternative strategies were proposed, assessed and implemented. For example, the multiple threats to the Florida panther in its existing habitat were recognised as probably insurmountable, and a captive breeding effort has been initiated for the purpose of securing the gene pool and providing animals for release in areas of former habitat. PVA modelling with VORTEX has often identified a single threat to which a species is particularly vulnerable. The small but growing population of Puerto Rican parrots was assessed to be secure, except for the risk of population decimation by hurricane. Recommendations were made to make available secure shelter for captive parrots and to move some of the birds to a site distant from the wild flock, in order to minimise the damage that could occur in a catastrophic storm. These recommended actions were only partly implemented when, in late 1989, a hurricane killed many of the wild parrots. The remaining population of about 350 Tana River red colobus were determined by PVA to be so fragmented that demographic and genetic processes within the 10 subpopulations destabilised population dynamics. Creation of habitat corridors may be necessary to prevent extinction of the taxon. In some cases, PVA modelling has been reassuring to managers: analysis of black rhinos in Kenya indicated that many of the populations within sanctuaries were recovering steadily. Some could soon be used to provide animals for re-establishment or supplementation of populations previously eliminated by poaching. For some species, available data were insufficient to allow definitive PVA with VORTEX. In such cases, the attempt at PVA modelling has made apparent the need for more data on population trends and processes, thereby helping to justify and guide research efforts.

Description of VORTEX

Overview

The VORTEX computer simulation model is a Monte Carlo simulation of the effects of deterministic forces, as well as demographic, environmental and genetic stochastic events, on wildlife populations. VORTEX models population dynamics as discrete, sequential events that occur according to probabilities that are random variables, following user-specified distributions. The input parameters used by VORTEX are summarised in the first part of the sample output given in the Appendix.

VORTEX simulates a population by stepping through a series of events that describe an annual cycle of a typical sexually reproducing, diploid organism: mate selection, reproduction, mortality, increment of age by one year, migration among populations, removals, supplementation, and then truncation (if necessary) to the carrying capacity. The program was designed to model long-lived species with low fecundity, such as mammals, birds and reptiles. Although it could and has been used in modelling highly fecund vertebrates and invertebrates, it is awkward to use in such cases as it requires complete specification of the percentage of females producing each possible clutch size. Moreover, computer memory limitations often hamper such analyses. Although VORTEX iterates life events on an annual cycle, a user could model 'years' that are other than 12 months' duration. The simulation of the population is itself iterated to reveal the distribution of fates that the population might experience.

Demographic Stochasticity

VORTEX models demographic stochasticity by determining the occurrence of probabilistic events such as reproduction, litter size, sex determination and death with a pseudo-random number generator. The probabilities of mortality and reproduction are sex-specific and pre-determined for each age class up to the age of breeding. It is assumed that reproduction and survival probabilities remain constant from the age of first breeding until a specified upper limit to age is reached. Sex ratio at birth is modelled with a user-specified constant probability of an offspring being male. For each life event, if the random value sampled from the uniform 0–1 distribution falls below the probability for that year, the event is deemed to have occurred, thereby simulating a binomial process.

The source code used to generate random numbers uniformly distributed between 0 and 1 was obtained from Maier (1991), according to the algorithm of Kirkpatrick and Stoll (1981). Random deviates from binomial distributions, with mean p and standard deviation s, are obtained by first determining the integral number of binomial trials, N, that would produce the value of s closest to the specified value, according to

$$N = p(1-p)/s^2 .$$

N binomial trials are then simulated by sampling from the uniform 0–1 distribution to obtain the desired result, the frequency or proportion of successes. If the value of N determined for a desired binomial distribution is larger than 25, a normal approximation is used in place of the binomial distribution. This normal approximation must be truncated at 0 and at 1 to allow use in defining probabilities, although, with such large values of N, s is small relative to p and the truncation would be invoked only rarely. To avoid introducing bias with this truncation, the normal approximation to the binomial (when used) is truncated symmetrically around the mean. The algorithm for generating random numbers from a unit normal distribution follows Latour (1986).

VORTEX can model monogamous or polygamous mating systems. In a monogamous system, a relative scarcity of breeding males may limit reproduction by females. In polygamous or monogamous models, the user can specify the proportion of the adult males in the breeding pool. Males are randomly reassigned to the breeding pool each year of the simulation, and all males in the breeding pool have an equal chance of siring offspring.

The 'carrying capacity', or the upper limit for population size within a habitat, must be specified by the user. VORTEX imposes the carrying capacity via a probabilistic truncation whenever the population exceeds the carrying capacity. Each animal in the population has an equal probability of being removed by this truncation.

Environmental Variation

VORTEX can model annual fluctuations in birth and death rates and in carrying capacity as might result from environmental variation. To model environmental variation, each demographic parameter is assigned a distribution with a mean and standard deviation that is specified by the user. Annual fluctuations in probabilities of reproduction and mortality are modelled as binomial distributions. Environmental variation in carrying capacity is modelled as a normal distribution. The variance across years in the frequencies of births and deaths resulting from the simulation model (and in real populations) will have two components: the demographic variation resulting from a binomial sampling around the mean for each year, and additional fluctuations due to environmental variation and catastrophes (see Fig. 1 and section on The Dynamics of Small Populations, above).

Data on annual variations in birth and death rates are important in determining the probability of extinction, as they influence population stability (Goodman 1987). Unfortunately, such field information is rarely available (but see Fig. 1). Sensitivity testing, the examination of a range of values when the precise value of a parameter is unknown, can help to identify whether the unknown parameter is important in the dynamics of a population.

Catastrophes

Catastrophes are modelled in VORTEX as random events that occur with specified probabilities. Any number of types of catastrophes can be modelled. A catastrophe will occur if a randomly generated number between zero and one is less than the probability of occurrence. Following a catastrophic event, the chances of survival and successful breeding for that simulated year are multiplied by severity factors. For example, forest fires might occur once in 50 years, on average, killing 25% of animals, and reducing breeding by survivors by 50% for the year. Such a catastrophe would be modelled as a random event with 0·02 probability of occurrence each year, and severity factors of 0·75 for survival and 0·50 for reproduction.

Genetic Processes

Genetic drift is modelled in VORTEX by simulation of the transmission of alleles at a hypothetical locus. At the beginning of the simulation, each animal is assigned two unique alleles. Each offspring is randomly assigned one of the alleles from each parent. Inbreeding depression is modelled as a loss of viability during the first year of inbred animals. The impacts of inbreeding are determined by using one of two models available within VORTEX: a Recessive Lethals model or a Heterosis model.

In the Recessive Lethals model, each founder starts with one unique recessive lethal allele and a unique, dominant non-lethal allele. This model approximates the effect of inbreeding if each individual in the starting population had one recessive lethal allele in its genome. The fact that the simulation program assumes that all the lethal alleles are at the same locus has a very minor impact on the probability that an individual will die because of homozygosity for one of the lethal alleles. In the model, homozygosity for different lethal alleles are mutually exclusive events, whereas in a multilocus model an individual could be homozygous for several lethal alleles simultaneously. By virtue of the death of individuals that are homozygous for lethal alleles, such alleles would be removed slowly by natural selection during the generations of a simulation. This reduces the genetic variation present in the population relative to the case with no inbreeding depression, but also diminishes the subsequent probability that inbred individuals will be homozygous for a lethal allele. This model gives an optimistic reflection of the impacts of inbreeding on many species, as the median number of lethal equivalents per diploid genome observed for mammalian populations is about three (Ralls *et al.* 1988).

The expression of fully recessive deleterious alleles in inbred organisms is not the only genetic mechanism that has been proposed as a cause of inbreeding depression. Some or most of the effects of inbreeding may be a consequence of superior fitness of heterozygotes (heterozygote advantage or 'heterosis'). In the Heterosis model, all homozygotes have reduced fitness compared with heterozygotes. Juvenile survival is modelled according to the logarithmic model developed by Morton *et al.* (1956):

$$\ln S = A - BF$$

in which S is survival, F is the inbreeding coefficient, A is the logarithm of survival in the absence of inbreeding, and B is a measure of the rate at which survival decreases with inbreeding. B is termed the number of 'lethal equivalents' per haploid genome. The number of lethal equivalents per diploid genome, $2B$, estimates the number of lethal alleles per individual in the population if all deleterious effects of inbreeding were due to recessive lethal alleles. A population in which inbreeding depression is one lethal equivalent per diploid genome may have one recessive lethal allele per individual (as in the Recessive Lethals model, above), it may have two recessive alleles per individual, each of which confer a 50% decrease in survival, or it may have some other combination of recessive deleterious alleles that equate in effect with one lethal allele per individual. Unlike the situation with fully recessive deleterious alleles, natural selection does not remove deleterious alleles at heterotic loci because all alleles are deleterious when homozygous and beneficial when present in heterozygous combination with other alleles. Thus, under the Heterosis model, the impact of inbreeding on survival does not diminish during repeated generations of inbreeding.

Unfortunately, for relatively few species are data available to allow estimation of the effects of inbreeding, and the magnitude of these effects varies considerably among species (Falconer 1981; Ralls *et al.* 1988; Lacy *et al.* 1993). Moreover, whether a Recessive Lethals model or a Heterosis model better describes the underlying mechanism of inbreeding depression and therefore the response to repeated generations of inbreeding is not well-known (Brewer *et al.* 1990), and could be determined empirically only from breeding studies that span many generations. Even without detailed pedigree data from which to estimate the number of lethal equivalents in a population and the underlying nature of the genetic load (recessive alleles or heterosis), applications of PVA must make assumptions about the effects of inbreeding on the population being studied. In some cases, it might be considered appropriate to assume that an inadequately studied species would respond to inbreeding in accord with the median (3·14 lethal equivalents per diploid) reported in the survey by Ralls *et al.* (1988). In other cases, there might be reason to make more optimistic assumptions (perhaps the lower quartile, 0·90 lethal equivalents), or more pessimistic assumptions (perhaps the upper quartile, 5·62 lethal equivalents).

Deterministic Processes

VORTEX can incorporate several deterministic processes. Reproduction can be specified to be density-dependent. The function relating the proportion of adult females breeding each year to the total population size is modelled as a fourth-order polynomial, which can provide a close fit to most plausible density-dependence curves. Thus, either positive population responses to low-density or negative responses (e.g. Allee effects), or more complex relationships, can be modelled.

Populations can be supplemented or harvested for any number of years in each simulation. Harvest may be culling or removal of animals for translocation to another (unmodelled) population. The numbers of additions and removals are specified according to the age and sex of animals. Trends in the carrying capacity can also be modelled in VORTEX, specified as an annual percentage change. These changes are modelled as linear, rather than geometric, increases or decreases.

Migration among Populations

VORTEX can model up to 20 populations, with possibly distinct population parameters. Each pairwise migration rate is specified as the probability of an individual moving from one population to another. This probability is independent of the age and sex. Because of between-population migration and managed supplementation, populations can be recolonised. VORTEX tracks the dynamics of local extinctions and recolonisations through the simulation.

Output

VORTEX outputs (1) probability of extinction at specified intervals (e.g., every 10 years during a 100-year simulation), (2) median time to extinction if the population went extinct in at least 50% of the simulations, (3) mean time to extinction of those simulated populations that became extinct, and (4) mean size of, and genetic variation within, extant populations (see Appendix and Lindenmayer *et al.* 1993).

Standard deviations across simulations and standard errors of the mean are reported for population size and the measures of genetic variation. Under the assumption that extinction of independently replicated populations is a binomial process, the standard error of the probability of extinction (*SE*) is reported by VORTEX as

$$SE(p) = \sqrt{[p \times (1-p)/n]}\,,$$

in which the frequency of extinction was p over n simulated populations. Demographic and genetic statistics are calculated and reported for each subpopulation and for the metapopulation.

Availability of the VORTEX Simulation Program

VORTEX Version 5.1 is written in the C programming language and compiled with the Lattice 80286C Development System (Lattice Inc.) for use on microcomputers using the MS-DOS (Microsoft Corp.) operating system. Copies of the compiled program and a manual for its use are available for nominal distribution costs from the Captive Breeding Specialist Group (Species Survival Commission, IUCN), 12101 Johnny Cake Ridge Road, Apple Valley, Minnesota 55124, U.S.A. The program has been tested by many workers, but cannot be guaranteed to be error-free. Each user retains responsibility for ensuring that the program does what is intended for each analysis.

Sequence of Program Flow

(1) The seed for the random number generator is initialised with the number of seconds elapsed since the beginning of the 20th century.

(2) The user is prompted for input and output devices, population parameters, duration of simulation, and number of interations.

(3) The maximum allowable population size (necessary for preventing memory overflow) is calculated as

$$N_{max} = (K + 3s) \times (1 + L)$$

in which K is the maximum carrying capacity (carrying capacity can be specified to change linearly for a number of years in a simulation, so the maximum carrying capacity can be greater than the initial carrying capacity), s is the annual environmental variation in the carrying capacity expressed as a standard deviation, and L is the specified maximum litter size. It is theoretically possible, but very unlikely, that a simulated population will exceed the calculated N_{max}. If this occurs then the program will give an error message and abort.

(4) Memory is allocated for data arrays. If insufficient memory is available for data arrays then N_{max} is adjusted downward to the size that can be accommodated within the available memory and a warning message is given. In this case it is possible that the analysis may have to be terminated because the simulated population exceeds N_{max}. Because N_{max} is often several-fold greater than the likely maximum population size in a simulation, a warning it has been adjusted downward because of limiting memory often will not hamper the analyses. Except for limitations imposed by the size of the computer memory (VORTEX can use extended memory, if available), the only limit to the size of the analysis is that no more than 20 populations exchanging migrants can be simulated.

(5) The expected mean growth rate of the population is calculated from mean birth and death rates that have been entered. Algorithms follow cohort life-table analyses (Ricklefs 1979). Generation time and the expected stable age distribution are also estimated. Life-table estimations assume no limitation by carrying capacity, no limitation of mates, and no loss of fitness due to inbreeding depression, and the estimated intrinsic growth rate assumes that the population is at the stable age distribution. The effects of catastrophes are incorporated into the life-table analysis by using birth and death rates that are weighted averages of the values in years with and without catastrophes, weighted by the probability of a catastrophe occurring or not occurring.

(6) Iterative simulation of the population proceeds via steps 7–26 below. For exploratory modelling, 100 iterations are usually sufficient to reveal gross trends among sets of simulations with different input parameters. For more precise examination of population behaviour under various scenarios, 1000 or more simulations should be used to minimise standard errors around mean results.

(7) The starting population is assigned an age and sex structure. The user can specify the exact age–sex structure of the starting population, or can specify an initial population size and request that the population be distributed according to the stable age distribution calculated from the life table. Individuals in the starting population are assumed to be unrelated. Thus, inbreeding can occur only in second and later generations.

(8) Two unique alleles at a hypothetical genetic locus are assigned to each individual in the starting population and to each individual supplemented to the population during the simulation. VORTEX therefore uses an infinite alleles model of genetic variation. The subsequent fate of genetic variation is tracked by reporting the number of extant alleles each year, the expected heterozygosity or gene diversity, and the observed heterozygosity. The expected heterozygosity, derived from the Hardy–Weinberg equilibrium, is given by

$$H_e = 1 - \Sigma(p_i^2)\,,$$

in which p_i is the frequency of allele i in the population. The observed heterozygosity is simply the proportion of the individuals in the simulated population that are heterozygous. Because of the starting assumption of two unique alleles per founder, the initial population has an observed heterozygosity of 1·0 at the hypothetical locus and only inbred animals can become homozygous. Proportional loss of heterozygosity by means of random genetic drift is independent of the initial heterozygosity and allele frequencies of a population (assuming that the initial value was not zero) (Crow and Kimura 1970), so the expected heterozygosity remaining in a simulated population is a useful metric of genetic decay for comparison across scenarios and populations. The mean observed heterozygosity reported by VORTEX is the mean inbreeding coefficient of the population.

(9) The user specifies one of three options for modelling the effect of inbreeding: (a) no effect of inbreeding on fitness, that is, all alleles are selectively neutral, (b) each founder individual has one unique lethal and one unique non-lethal allele (Recessive Lethals option), or (c) first-year survival of each individual is exponentially related to its inbreeding coefficient (Heterosis option). The first case is clearly an optimistic one, as almost all diploid

populations studied intensively have shown deleterious effects of inbreeding on a variety of fitness components (Wright 1977; Falconer 1981). Each of the two models of inbreeding depression may also be optimistic, in that inbreeding is assumed to have an impact only on first-year survival. The Heterosis option allows, however, for the user to specify the severity of inbreeding depression on juvenile survival.

(10) Years are iterated via steps 11–25 below.

(11) The probabilities of females producing each possible litter size are adjusted to account for density dependence of reproduction (if any).

(12) Birth rate, survival rates and carrying capacity for the year are adjusted to model environmental variation. Environmental variation is assumed to follow binomial distributions for birth and death rates and a normal distribution for carrying capacity, with mean rates and standard deviations specified by the user. At the outset of each year a random number is drawn from the specified binomial distribution to determine the percentage of females producing litters. The distribution of litter sizes among those females that do breed is maintained constant. Another random number is drawn from a specified binomial distribution to model the environmental variation in mortality rates. If environmental variations in reproduction and mortality are chosen to be correlated, the random number used to specify mortality rates for the year is chosen to be the same percentile of its binomial distribution as was the number used to specify reproductive rate. Otherwise, a new random number is drawn to specify the deviation of age- and sex-specific mortality rates for their means. Environmental variation across years in mortality rates is always forced to be correlated among age and sex classes.

The carrying capacity (K) of the year is determined by first increasing or decreasing the carrying capacity at year 1 by an amount specified by the user to account for linear changes over time. Environmental variation in K is then imposed by drawing a random number from a normal distribution with the specified values for mean and standard deviation.

(13) Birth rates and survival rates for the year are adjusted to model any catastrophes determined to have occurred in that year.

(14) Breeding males are selected for the year. A male of breeding age is placed into the pool of potential breeders for that year if a random number drawn for that male is less than the proportion of breeding-age males specified to be breeding.

(15) For each female of breeding age, a mate is drawn at random from the pool of breeding males for that year. The size of the litter produced by that pair is determined by comparing the probabilities of each potential litter size (including litter size of 0, no breeding) to a randomly drawn number. The offspring are produced and assigned a sex by comparison of a random number to the specified sex ratio at birth. Offspring are assigned, at random, one allele at the hypothetical genetic locus from each parent.

(16) If the Heterosis option is chosen for modelling inbreeding depression, the genetic kinship of each new offspring to each other living animal in the population is determined. The kinship between a new animal, A, and another existing animal, B is

$$f_{AB} = 0{\cdot}5 \times (f_{MB} + f_{PB})$$

in which f_{ij} is the kinship between animals i and j, M is the mother of A, and P is the father of A. The inbreeding coefficient of each animal is equal to the kinship between its parents, $F = f_{MP}$, and the kinship of an animal to itself is $f_{AA} = 0{\cdot}5 \times (1 + F)$. [See Ballou (1983) for a detailed description of this method for calculating inbreeding coefficients.]

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If the Heterosis model of inbreeding depression is used and an individual is inbred, the survival probability is multiplied by e^{-bF} in which b is the number of lethal equivalents per haploid genome.

If the Recessive Lethals model is used, all offspring that are homozygous for a lethal allele are killed.

(18) The age of each animal is incremented by 1, and any animal exceeding the maximum age is killed.

(19) If more than one population is being modelled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age–sex class, VORTEX continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assigned two unique alleles, one of which will be a recessive lethal in the Recessive Lethals model of inbreeding depression. Each immigrant is assumed to be genetically unrelated to all other individuals in the population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size (N) exceeds the carrying capacity (K) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to $(N-K)/N$, so that the expected population size after the additional mortality is K.

(25) Summary statistics on population size and genetic variation are tallied and reported. A simulated population is determined to be extinct if one of the sexes has no representatives.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate, are calculated across iterations and printed out.

Assumptions Underpinning VORTEX

It is impossible to simulate the complete range of complex processes that can have an impact on wild populations. As a result there are necessarily a range of mathematical and biological assumptions that underpin any PVA program. Some of the more important assumptions in VORTEX include the following.

(1) Survival probabilities are density independent when population size is less than carrying capacity. Additional mortality imposed when the population exceeds K affects all age and sex classes equally.

(2) The relationship between changes in population size and genetic variability are examined for only one locus. Thus, potentially complex interactions between genes located on the same chromosome (linkage disequilibrium) are ignored. Such interactions are typically associated with genetic drift in very small populations, but it is unknown if, or how, they would affect population viability.

(3) All animals of reproductive age have an equal probability of breeding. This ignores the likelihood that some animals within a population may have a greater probability of breeding successfully, and breeding more often, than other individuals. If breeding is not at random among those in the breeding pool, then decay of genetic variation and inbreeding will occur more rapidly than in the model.

(4) The life-history attributes of a population (birth, death, migration, harvesting, supplementation) are modelled as a sequence of discrete and therefore seasonal events. However, such events are often continuous through time and the model ignores the possibility that they may be aseasonal or only partly seasonal.

(5) The genetic effects of inbreeding on a population are determined in VORTEX by using one of two possible models: the Recessive Lethals model and the Heterosis model. Both models have attributes likely to be typical of some populations, but these may vary within and between species (Brewer *et al.* 1990). Given this, it is probable that the impacts of inbreeding will fall between the effects of these two models. Inbreeding is assumed to depress only one component of fitness: first-year survival. Effects on reproduction could be incorporated into this component, but longer-term impacts such as increased disease susceptibility or decreased ability to adapt to environmental change are not modelled.

(6) The probabilities of reproduction and mortality are constant from the age of first breeding until an animal reaches the maximum longevity. This assumes that animals continue to breed until they die.

(7) A simulated catastrophe will have an effect on a population only in the year that the event occurs.

(8) Migration rates among populations are independent of age and sex.

(9) Complex, interspecies interactions are not modelled, except in that such community dynamics might contribute to random environmental variation in demographic parameters. For example, cyclical fluctuations caused by predator–prey interactions cannot be modelled by VORTEX.

Discussion

Uses and Abuses of Simulation Modelling for PVA

Computer simulation modelling is a tool that can allow crude estimation of the probability of population extinction, and the mean population size and amount of genetic diversity, from data on diverse interacting processes. These processes are too complex to be integrated intuitively and no analytic solutions presently, or are likely to soon, exist. PVA modelling focuses on the specifics of a population, considering the particular habitat, threats, trends, and time frame of interest, and can only be as good as the data and the assumptions input to the model (Lindenmayer *et al.* 1993). Some aspects of population dynamics are not modelled by VORTEX nor by any other program now available. In particular, models of single-species dynamics, such as VORTEX, are inappropriate for use on species whose fates are strongly determined by interactions with other species that are in turn undergoing complex (and perhaps synergistic) population dynamics. Moreover, VORTEX does not model many conceivable and perhaps important interactions among variables. For example, loss of habitat might cause secondary changes in reproduction, mortality, and migration rates, but ongoing trends in these parameters cannot be simulated with VORTEX. It is important to stress that PVA does not predict in general what will happen to a population; PVA forecasts the likely effects only of those factors incorporated into the model.

Yet, the use of even simplified computer models for PVA can provide more accurate predictions about population dynamics than the even more crude techniques available previously, such as calculation of expected population growth rates from life tables. For the purpose of estimating extinction probabilities, methods that assess only deterministic factors are almost certain to be inappropriate, because populations near extinction will commonly be so small that random processes dominate deterministic ones. The suggestion by Mace and Lande (1991) that population viability be assessed by the application of simple rules (e.g., a taxon be considered Endangered if the total effective population size is below 50 or the total census size below 250) should be followed only if knowledge is insufficient to allow more accurate quantitative analysis. Moreover, such preliminary judgments, while often important in stimulating appropriate corrective measures, should signal, not obviate, the need for more extensive investigation and analysis of population processes, trends and threats.

Several good population simulation models are available for PVA. They differ in capabilities, assumptions and ease of application. The ease of application is related to the number of simplifying assumptions and inversely related to the flexibility and power of the model. It is unlikely that a single or even a few simulation models will be appropriate for all PVAs. The VORTEX program has some capabilities not found in many other population simulation programs, but is not as flexible as are some others (e.g., GAPPS; Harris *et al.* 1986). VORTEX is user-friendly and can be used by those with relatively little understanding of population biology and extinction processes, which is both an advantage and a disadvantage.

Testing Simulation Models

Because many population processes are stochastic, a PVA can never specify what will happen to a population. Rather, PVA can provide estimates of probability distributions describing possible fates of a population. The fate of a given population may happen to fall at the extreme tail of such a distribution even if the processes and probabilities are assessed precisely. Therefore, it will often be impossible to test empirically the accuracy of PVA results by monitoring of one or a few threatened populations of interest. Presumably, if a population followed a course that was well outside of the range of possibilities predicted by a model, that model could be rejected as inadequate. Often, however, the range of plausible fates generated by PVA is quite broad.

Simulation programs can be checked for internal consistency. For example, in the absence of inbreeding depression and other confounding effects, does the simulation model predict an average long-term growth rate similar to that determined from a life-table calculation? Beyond this, some confidence in the accuracy of a simulation model can be obtained by comparing observed fluctuations in population numbers to those generated by the model, thereby comparing a data set consisting of tens to hundreds of data points to the results of the model. For example, from 1938 to 1991, the wild population of whooping cranes had grown at a mean exponential rate, r, of 0·040, with annual fluctuations in the growth rate, SD (r), of 0·141 (Mirande *et al.* 1993). Life-table analysis predicted an r of 0·052. Simulations using VORTEX predicted an r of 0·046 into the future, with a SD (r) of 0·081. The lower growth rate projected by the stochastic model reflects the effects of inbreeding and perhaps imbalanced sex ratios among breeders in the simulation, factors that are not considered in deterministic life-table calculations. Moreover, life-table analyses use mean birth and death rates to calculate a single estimate of the population growth rate. When birth and death rates are fluctuating, it is more appropriate to average the population growth rates calculated separately from birth and death rates for each year. This mean growth rate would be lower than the growth rate estimated from mean life-table values.

When the simulation model was started with the 18 cranes present in 1938, it projected a population size in 1991 ($N \pm SD = 151 \pm 123$) almost exactly the same as that observed ($N = 146$). The large variation in population size across simulations, however, indicates that very different fates (including extinction) were almost equally likely. The model slightly underestimated the annual fluctuations in population growth [model SD $(r) = 0{\cdot}112$ *v.* actual SD $(r) = 0{\cdot}141$]. This may reflect a lack of full incorporation of all aspects of stochasticity into the model, or it may simply reflect the sampling error inherent in stochastic phenomena. Because the data input to the model necessarily derive from analysis of past trends, such retrospective analysis should be viewed as a check of consistency, not as proof that the model correctly describes current population dynamics. Providing another confirmation of consistency, both deterministic calculations and the simulation model project an over-wintering population of whooping cranes consisting of 12% juveniles (less than 1 year of age), while the observed frequency of juveniles at the wintering grounds in Texas has averaged 13%.

Convincing evidence of the accuracy, precision and usefulness of PVA simulation models would require comparison of model predictions to the distribution of fates of many replicate populations. Such a test probably cannot be conducted on any endangered species, but could and should be examined in experimental non-endangered populations. Once simulation models are determined to be sufficiently descriptive of population processes, they can guide management of threatened and endangered species (see above and Lindenmayer *et al.* 1993). The use of PVA modelling as a tool in an adaptive management framework (Clark *et al.* 1990) can lead to increasingly effective species recovery efforts as better data and better models allow more thorough analyses.

Directions for Future Development of PVA Models

The PVA simulation programs presently available model life histories as a series of discrete (seasonal) events, yet many species breed and die throughout much of the year. Continuous-time models would be more realistic and could be developed by simulating the time between life-history events as a random variable. Whether continuous-time models would significantly improve the precision of population viability estimates is unknown. Even more realistic models might treat some life-history events (e.g., gestation, lactation) as stages of specified duration, rather than as instantaneous events.

Most PVA simulation programs were designed to model long-lived, low fecundity (K-selected) species such as mammals, birds and reptiles. Relatively little work has been devoted to developing models for short-lived, high-fecundity (r-selected) species such as many amphibians and insects. Yet, the viability of populations of r-selected species may be highly affected by stochastic phenomena, and r-selected species may have much greater minimum viable populations than do most K-selected species. Assuring viability of K-selected species in a community may also afford adequate protection for r-selected species, however, because of the often greater habitat-area requirements of large vertebrates. Populations of r-selected species are probably less affected by intrinsic demographic stochasticity because large numbers of progeny will minimise random fluctuations, but they are more affected by environmental variations across space and time. PVA models designed for r-selected species would probably model fecundity as a continuous distribution, rather than as a completely specified discrete distribution of litter or clutch sizes; they might be based on life-history stages rather than time-increment ages; and they would require more detailed and accurate description of environmental fluctuations than might be required for modelling K-selected species.

The range of PVA computer simulation models becoming available is important because the different assumptions of the models provide capabilities for modelling diverse life histories. Because PVA models always simplify the life history of a species, and because the assumptions of no model are likely to match exactly our best understanding of the dynamics of a population of interest, it will often be valuable to conduct PVA modelling with several simulation programs and to compare the results. Moreover, no computer program can be guaranteed to be free of errors. There is a need for researchers to compare results from different PVA models when applied to the same analysis, to determine how the different assumptions affect conclusions and to cross-validate algorithms and computer code.

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References

Akçakaya, H. R., and Ferson, S. (1990). 'RAMAS/Space User Manual. Spatially Structured Population Models for Conservation Biology.' (Applied Biomathematics: Setauket, New York.)

Ballou, J. (1983). Calculating inbreeding coefficients from pedigrees. In 'Genetics and Conservation: A Reference for Managing Wild Animal and Plant Populations'. (Eds C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde and W. L. Thomas.) pp. 509–20. (Benjamin/Cummings: Menlo Park, California.)

Belovsky, G. E. (1987). Extinction models and mammalian persistence. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 35–57. (Cambridge University Press: Cambridge.)

Berger, J. (1990). Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. *Conservation Biology* **4**, 91–8.

Brewer, B. A., Lacy, R. C., Foster, M. L., and Alaks, G. (1990). Inbreeding depression in insular and central populations of *Peromyscus* mice. *Journal of Heredity* **81**, 257–66.

Burgmann, M. A., and Gerard, V. A. (1990). A stage-structured, stochastic model for giant kelp *Macrocystis pyrifera*. *Marine Biology* **105**, 15–23.

Clark, T. W. (1989). 'Conservation Biology of the Black-footed Ferret. Special Scientific Report.' (Wildlife Preservation Trust International: Philadelphia.)

Clark, T. W., and Seebeck, J. H. (Eds) (1990). 'Management and Conservation of Small Populations.' (Chicago Zoological Society: Brookfield, Illinois.)

Clark, T. W., Warneke, R. M., and George, G. G. (1990). Management and conservation of small populations. In 'Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 1–18. (Chicago Zoological Society: Brookfield, Illinois.)

Clark, T. W., Backhouse, G. N., and Lacy, R. C. (1991). Report of a workshop on population viability assessment as a tool for threatened species management and conservation. *Australian Zoologist* **27**, 28–35.

Crow, J. F., and Kimura, M. (1970). 'Introduction to Population Genetics Theory.' (Harper and Row: New York.)

Doughty, R. W. (1989). 'Return of the Whooping Crane.' (University of Texas Press: Austin.)

Falconer, D. S. (1981). 'Introduction to Quantitative Genetics.' 2nd Edn. (Longman: New York.)

Ferson, S. (1990). 'RAMAS/Stage. Generalized Stage-based Modeling for Population Dynamics.' (Applied Biomathematics: Setauket, New York.)

Ferson, S., and Akçakaya, H. R. (1989). 'RAMAS/Age User Manual. Modeling Fluctuations in Age-structured Populations.' (Applied Biomathematics: Setauket, New York.)

Fisher, R. A. (1958). 'The Genetical Theory of Natural Selection.' 2nd Edn. (Dover: New York.)

Foose, T. J., Lacy, R. C., Brett, R., and Seal, U. S. (1992). Kenya black rhinoceros population and habitat viability assessment. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Gilpin, M. E. (1987). Spatial structure and population vulnerability. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 125–39. (Cambridge University Press: Cambridge.)

Gilpin, M. E. (1989). Population viability analysis. *Endangered Species Update* **6**, 15–18.

Gilpin, M. E., and Soulé, M. E. (1986). Minimum viable populations: processes of species extinction. In 'Conservation Biology: the Science of Scarcity and Diversity'. (Ed. M. E. Soulé.) pp. 19–34. (Sinauer: Sunderland, Massachusetts.)

Goodman, D. (1987). The demography of chance extinction. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 11–34. (Cambridge University Press: Cambridge.)

Grier, J. W. (1980*a*). A simulation model for small populations of animals. *Creative Computing* **6**, 116–21.

Grier, J. W. (1980*b*). Modeling approaches for bald eagle population dynamics. *Wildlife Society Bulletin* **8**, 316–22.

Harris, R. B., Metzger, L. H., and Bevins, C. D. (1986). 'GAPPS. Version 3.0.' (Montana Cooperative Research Unit, University of Montana: Missoula.)

Hill, F. A. R. (1991). A research recovery plan for the brush-tailed rock wallaby *Petrogale pencillata* (Gray 1825). Report to Australian National Parks and Wildlife Service. (Department of Conservation and Environment: Melbourne.)

Kirkpatrick, S., and Stoll, E. (1981). A very fast shift-register sequence random number generator. *Journal of Computational Physics* **40**, 517.

Lacy, R. C. (1993). Impacts of inbreeding in natural and captive populations of vertebrates: implications for conservation. *Perspectives in Biology and Medicine*. (In press.)

Lacy, R. C., and Clark, T. W. (1990). Population viability assessment of eastern barred bandicoot. In 'The Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 131–46. (Chicago Zoological Society: Brookfield, Illinois.)

Lacy, R. C., Flesness, N. R., and Seal, U. S. (1989). 'Puerto Rican Parrot Population Viability Analysis.' (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Lacy, R. C., Petric, A. M., and Warneke, M. (1993). Inbreeding and outbreeding depression in captive populations of wild species. In 'The Natural History of Inbreeding and Outbreeding'. (Ed. N. W. Thornhill.) (University of Chicago Press: Chicago.) (In press.)

Lande, R. (1988). Demographic models of the northern spotted owl (*Strix occidentalis caurina*). *Oecologia* **75**, 601–7.

Latour, A. (1986). Polar normal distribution. *Byte* August 1986, 131–2.

Lindenmayer, D. B., Clark, T. W., Lacy, R. C., and Thomas, V. C. (1993). Population viability analysis as a tool in wildlife management: a review with reference to Australia. *Environmental Management*. (In press.)

Mace, G. M., and Lande, R. (1991). Assessing extinction threats: toward a reevaluation of IUCN threatened species categories. *Conservation Biology* **5**, 148–57.

Maguire, L. A., Lacy, R. C., Begg, R. J., and Clark, T. W. (1990). An analysis of alternative strategies for recovering the eastern barred bandicoot. In 'The Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 147–64. (Chicago Zoological Society: Brookfield, Illinois.)

Maier, W. L. (1991). A fast pseudo random number generator. *Dr. Dobb's Journal* May 1991, 152–7.

Mirande, C., Lacy, R. C., and Seal, U. S. (1993). Whooping crane conservation viability assessment workshop. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Morton, N. E., Crow, J. F., and Muller, H. J. (1956). An estimate of the mutational damage in man from data on consanguineous marriages. *Proceedings of the National Academy of Sciences, U.S.A.* **42**, 855–63.

O'Brien, S. J., and Evermann, J. F. (1988). Interactive influence of infectious diseases and genetic diversity in natural populations. *Trends in Ecology and Evolution* **3**, 254–9.

Possingham, H., Davies, I., and Noble, I. R. (1991). 'An Evaluation of Population Viability Analysis for Assessing the Risk of Extinction.' (Resource Assessment Commission: Canberra.)

Possingham, H. P., Davies, I., Noble, I. R., and Norton, T. W. (1992). A metapopulation simulation model for assessing the likelihood of plant and animal extinctions. *Mathematics and Computers in Simulation* **33**, 367–72.

Ralls, K., Ballou, J. D., and Templeton, A. R. (1988). Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* **2**, 185–93.

Resource Assessment Commission (1991). Forest and timber inquiry. Draft report. Vol. 2. July 1991. (Australian Government Publishing Service: Canberra.)

Ricklefs, R. E. (1979). 'Ecology.' 2nd Edn. (Chiron: New York.)

Robertson, A. (1960). A theory of limits in artificial selection. *Proceedings of the Royal Society of London* **153B**, 234–49.

Seal, U. S., and Foose, T. J. (1989). Javan rhinoceros population viability analysis and recommendations. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., and Lacy, R. C. (1989). Florida panther population viability analysis. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., Ballou, J. D., and Padua, C. V. (1990). *Leontopithecus* population viability analysis workshop report. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., Lacy, R. C., Medley, K., Seal, R., and Foose, T. J. (1991). Tana River Primate Reserve Conservation Assessment Workshop. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Selander, R. K. (1983). Evolutionary consequences of inbreeding. In 'Genetics and Conservation: A Reference for Managing Wild Animal and Plant Populations'. (Eds C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde and W. L. Thomas.) pp. 201–15. (Benjamin/Cummings: Menlo Park, California.)

Shaffer, M. L. (1981). Minimum population sizes for species conservation. *BioScience* **31**, 131–4.

Shaffer, M. L. (1987). Minimum viable populations: coping with uncertainty. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 69–86. (Cambridge University Press: Cambridge.)

Shaffer, M. L. (1990). Population viability analysis. *Conservation Biology* **4**, 39–40.

Simberloff, D. A. (1986). The proximate causes of extinction. In 'Patterns and Processes in the History of Life'. (Eds D. M. Raup and D. Jablonski.) pp. 259–76. (Springer-Verlag: Berlin.)

Simberloff, D. A. (1988). The contribution of population and community biology to conservation science. *Annual Review of Ecology and Systematics* **19**, 473–511.

Soulé, M. E. (Ed.) (1987). 'Viable Populations for Conservation.' (Cambridge University Press: Cambridge.)

Thomas, C. D. (1990). What do real population dynamics tell us about minimum population sizes? *Conservation Biology* **4**, 324–7.

Wright, S. (1977). 'Evolution and the Genetics of Populations. Vol. 3. Experimental Results and Evolutionary Deductions.' (University of Chicago Press: Chicago.)

Appendix. Sample Output from VORTEX

Explanatory comments are added in italics

VORTEX – simulation of genetic and demographic stochasticity

TEST — *Simulation label and output file name*

Fri Dec 20 09:21:18 1991

2 population(s) simulated for 100 years, 100 runs

VORTEX first lists the input parameters used in the simulation:

HETEROSIS model of inbreeding depression
with 3·14 lethal equivalents per diploid genome

Migration matrix:

	1	2
1	0·9900	0·0100
2	0·0100	0·9900

i.e. 1% probability of migration from Population 1 to 2, and from Population 2 to 1

First age of reproduction for females: 2 for males: 2
Age of senescence (death): 10
Sex ratio at birth (proportion males): 0·5000

Population 1:

Polygynous mating; 50·00 per cent of adult males in the breeding pool.
Reproduction is assumed to be density independent.
50·00 (EV = 12·50 SD) per cent of adult females produce litters of size 0
25·00 per cent of adult females produce litters of size 1
25·00 per cent of adult females produce litters of size 2
EV is environmental variation
50·00 (EV = 20·41 SD) per cent mortality of females between ages 0 and 1
10·00 (EV = 3·00 SD) per cent mortality of females between ages 1 and 2
10·00 (EV = 3·00 SD) per cent annual mortality of adult females (2 <= age <= 10)
50·00 (EV = 20·41 SD) per cent mortality of males between ages 0 and 1
10·00 (EV = 3·00 SD) per cent mortality of males between ages 1 and 2
10·00 (EV = 3·00 SD) per cent annual mortality of adult males (2 <= age <= 10)

EVs have been adjusted to closest values possible for binomial distribution.
EV in reproduction and mortality will be correlated.
Frequency of type 1 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival
Frequency of type 2 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival

Initial size of Population 1: (set to reflect stable age distribution)

Age	1	2	3	4	5	6	7	8	9	10	Total	
	1	0	1	1	0	1	0	0	1	0	5	Males
	1	0	1	1	0	1	0	0	1	0	5	Females

Carrying capacity = 50 (EV = 0·00 SD)
with a 10·000 per cent decrease for 5 years.

Animals harvested from population 1, year 1 to year 10 at 2 year intervals:
1 females 1 years old
1 female adults (2<=age<=10)
1 males 1 years old
1 male adults (2<=age<=10)

Animals added to population 1, year 10 through year 50 at 4 year intervals:
1 females 1 years old
1 females 2 years old
1 males 1 years old
1 males 2 years old

Input values are summarised above, results follow.

VORTEX now reports life-table calculations of expected population growth rate.

Deterministic population growth rate (based on females, with assumptions of no limitation of mates and no inbreeding depression):
r = −0·001 lambda = 0·999 RO = 0·997
Generation time for: females = 5·28 males = 5·28

Note that the deterministic life-table calculations project approximately zero population growth for this population.

Stable age distribution:

Age class	females	males
0	0·119	0·119
1	0·059	0·059
2	0·053	0·053
3	0·048	0·048
4	0·043	0·043
5	0·038	0·038
6	0·034	0·034
7	0·031	0·031
8	0·028	0·028
9	0·025	0·025
10	0·022	0·022

Ratio of adult (>=2) males to adult (>=2) females: 1·000

Population 2:

Input parameters for Population 2 were identical to those for Population 1.
Output would repeat this information from above.

Simulation results follow.

Population1

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 4·36 (0·10 SE, 1·01 SD)
Expected heterozygosity = 0·880 (0·001 SE, 0·012 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 8·57 (0·15 SE, 1·50 SD)

Population summaries given, as requested by user, at 10-year intervals.

Year 100

N[Extinct] = 86, P[E] = 0·860
N[Surviving] = 14, P[S] = 0·140
Population size = 8·14 (1·27 SE, 4·74 SD)
Expected heterozygosity = 0·577 (0·035 SE, 0·130 SD)
Observed heterozygosity = 0·753 (0·071 SE, 0·266 SD)
Number of extant alleles = 3·14 (0·35 SE, 1·29 SD)

In 100 simulations of 100 years of Population1:
86 went extinct and 14 survived.
This gives a probability of extinction of 0·8600 (0·0347 SE),
or a probability of success of 0·1400 (0·0347 SE).
99 simulations went extinct at least once.
Median time to first extinction was 5 years.
Of those going extinct,
mean time to first extinction was 7·84 years (1·36 SE, 13·52 SD).
123 recolonisations occurred.
Mean time to recolonisation was 4·22 years (0·23 SE, 2·55 SD).
110 re-extinctions occurred.
Mean time to re-extinction was 54·05 years (2·81 SE, 29·52 SD).

Mean final population for successful cases was 8·14 (1·27 SE, 4·74 SD)

Age 1	Adults	Total	
0·14	3·86	4·00	Males
0·36	3·79	4·14	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0889 (0·0121 SE, 0·4352 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0267 (0·0026 SE, 0·2130 SD)

Population growth in the simulation (r = −0·0267) was depressed relative to the projected growth rate calculated from the life table (r = −0·001) because of inbreeding depression and occasional lack of available mates.

Note: 497 of 1000 harvests of males and 530 of 1000 harvests of females could not be completed because of insufficient animals.

Final expected heterozygosity was 0·5768 (0·0349 SE, 0·1305 SD)
Final observed heterozygosity was 0·7529 (0·0712 SE, 0·2664 SD)
Final number of alleles was 3·14 (0·35 SE, 1·29 SD)

Population2

Similar results for Population 2, omitted from this Appendix, would follow.

******** Metapopulation Summary ********

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 8·65 (0·16 SE, 1·59 SD)
Expected heterozygosity = 0·939 (0·000 SE, 0·004 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 16·92 (0·20 SE, 1·96 SD)

Metapopulation summaries are given at 10-year intervals.

Year 100

N[Extinct] = 79, P[E] = 0·790
N[Surviving] = 21, P[S] = 0·210
Population size = 10·38 (1·37 SE, 6·28 SD)
Expected heterozygosity = 0·600 (0·025 SE, 0·115 SD)
Observed heterozygosity = 0·701 (0·050 SE, 0·229 SD)
Number of extant alleles = 3·57 (0·30 SE, 1·36 SD)

In 100 simulations of 100 years of Metapopulation:
79 went extinct and 21 survived.
This gives a probability of extinction of 0·7900 (0·0407 SE),
or a probability of success of 0·2100 (0·0407 SE).
97 simulations went extinct at least once.
Median time to first extinction was 7 years.
Of those going extinct,
mean time to first extinction was 11·40 years (2·05 SE, 20·23 SD).
91 recolonisations occurred.
Mean time to recolonisation was 3·75 years (0·15 SE, 1·45 SD).
73 re-extinctions occurred.
Mean time to re-extinction was 76·15 years (1·06 SE, 9·05 SD).

Mean final population for successful cases was 10·38 (1·37 SE, 6·28 SD)

Age 1	Adults	Total	
0·48	4·71	5·19	Males
0·48	4·71	5·19	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0545 (0·0128 SE, 0·4711 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0314 (0·0021 SE, 0·1743 SD)

Final expected heterozygosity was 0·5997 (0·0251 SE, 0·1151 SD)
Final observed heterozygosity was 0·7009 (0·0499 SE, 0·2288 SD)
Final number of alleles was 3·57 (0·30 SE, 1·36 SD)

Manuscript received 4 March 1992; revised and accepted 13 August 1992

Conservation Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union

Input Data Required for VORTEX

1) **Do you want to incorporate inbreeding depression?** Yes or No __________
Yes, if you think inbreeding might cause a reduction in fertility or survival
No, if you think inbreeding would not cause any negative impact

If you answered "Yes" to Question 1), then we need to specify the severity of the impacts of inbreeding by answering the following two questions:

1A) **How many lethal equivalents exist in your population?** ________
"Lethal equivalents" is a measure of the severity of effects of inbreeding on juvenile survival. The median value reported by Ralls et al. (1988) for 40 mammal populations was 3.14. The range for mammals reported in the literature is from 0.0 (no effect of inbreeding on survival) to about 15 (most inbred progeny die).

1B) **What proportion of the total lethal equivalents is due to recessive lethal alleles?** _______
This question relates to how easily natural selection would remove deleterious genes if inbreeding persisted for many generations (and the population did not become extinct). In other words, how well does the population adapt to inbreeding? The question is really asking this: what fraction of the genes responsible for inbreeding depression would be removed by selection over many generations? Unfortunately, little data exist for mammals regarding this question; data on fruit flies and rodents, however, suggest that about 50% of the total suite of inbreeding effects are, on average, due to lethal alleles.

2) **Do you want environmental variation in reproduction to be correlated with environmental variation in survival?** Yes or No ________
Answering "Yes" would indicate that good years for breeding are also good years for survival, and bad years for breeding are also bad years for survival. "No" would indicate that annual fluctuations in breeding and survival are independent.

3) Breeding system: Monogamous or Polygynous? ________

4) At what age do females begin breeding? ________

5) At what age do males begin breeding? ________
For each sex, we need to specify the age at which the typical animal produces its first litter. The age at which they "begin breeding" refers to their age when the offspring are actually born, and not when the parents mate.

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6) Maximum age? ________
When do they become reproductively senescent? VORTEX will allow them to breed (if they happen to live this long) up to this maximum age.

7) What is the sex ratio of offspring at birth? ________
What proportion of the year's offspring are males?

8) What is the maximum litter size? ________

9) In the average year, what proportion of adult females produce a litter? ________

10) How much does the proportion of females that breed vary across years?
Ideally, we need this value specified as a standard deviation (SD) of the proportion breeding. If long-term quantitative data are lacking, we can estimate this variation in several ways. At the simplest intuitive level, in about 67% of the years the proportion of adult females breeding would fall within 1 SD of the mean, so (mean value) + SD might represent the breeding rate in a typically "good" year, and (mean value) – SD might be the breeding rate in a typically "bad" year.

11) Of litters that are born in a given year, what percentage have litters of …
1 offspring? ________
2 offspring? ________
3 offspring? ________
4 offspring? ________
(and so on to the maximum litter size).

12) What is the percent survival of females …
from birth to 1 year of age? ________
from age 1 to age 2? ________
from age 2 to age 3? ________ (no need to answer this if they begin breeding at age 2)
from age *x* to age *x*+1, for adults? ________

13) What is the percent survival of males …
from birth to 1 year of age? ________
from age 1 to age 2? ________
from age 2 to age 3? ________ (no need to answer this if they begin breeding at age 2)
from age *x* to age *x*+1, for adults? ________

14) For each of the survival rates listed above, enter the variation across years as a standard deviation:
For females, what is the standard deviation in the survival rate
from birth to 1 year of age? ________
from age 1 to age 2? ________
from age 2 to age 3? ________ (no need to answer this if they begin breeding at age 2)
from age *x* to age *x*+1, for adults? ________

For males, what is the standard deviation in the survival rated
from birth to 1 year of age? ________
from age 1 to age 2? ________
from age 2 to age 3? ________ (no need to answer this if they begin breeding at age 2)
from age *x* to age *x*+1, for adults? ________

15) How many types of catastrophes should be included in the models? ________

You can model disease epidemics, or any other type of disaster, which might kill many individuals or cause major breeding failure in sporadic years.

16) For each type of catastrophe considered in Question 15),
What is the probability of occurrence? ________
(i.e., how often does the catastrophe occur in a given time period, say, 100 years?)
What is the reproductive rate in a catastrophe year relative to reproduction in normal years? ________
(i.e., 1.00 = no reduction in breeding; 0.75 = 25% reduction; 0.00 = no breeding)
What is the survival rate in a catastrophe year relative to survival in normal years? ________
(i.e., 1.00 = no reduction in breeding; 0.75 = 25% reduction; 0.00 = no breeding)

17) Are all adult males in the "pool" of potential breeders each year? Yes or No ________
(Are there some males that are excluded from the group of available breeders because they are socially prevented from holding territories, are sterile, or otherwise prevented from having access to mates?)

18) If you answered "No" to Question 17), then answer at least one of the following:
What percentage of adult males is available for breeding each year? ________
or
What percentage of adult males typically sires a litter each year? ________
or
How many litters are sired by the average breeding male (of those that sired at least one litter)? _____

19) What is the current population size? ________
(We will assume that the population starts at a "stable age distribution", rather than specifying ages of individual animals in the current population.)

20) What is the habitat carrying capacity? ________
(How many animals could be supported in the existing habitat?)
(We will assume that the habitat is not fluctuating randomly in quality over time.)

21) Will habitat be lost or gained over time? Yes or No ________
If you answered Yes to Question 21), then …

22) Over how many years will habitat be lost or gained? ________

23) What percentage of habitat will be lost or gained each year? ________

24) Will animals be removed from the wild population (to bolster captive stocks or for other reasons) ?
Yes or No ________
If "Yes", then,
At what annual interval? ________
For how many years? ________
How many female juveniles? _______ 1-2 year old females? _______ 2-3 year old females? _______ adult females? ________ will be removed each time.
How many male juveniles? _______ 1-2 year old males? _______ 2-3 year old males? _______ adult males? ________ will be removed each time.

25) Will animals be added to the population (from captive stocks, etc.)? Yes or No ________
If "Yes", then,
At what annual interval? ________

For how many years? ________
How many female 0-1 years? _______ 1-2 year old females? _______ 2-3 year old females? _______ adult females? ________ will be added each time.
How many male 0-1 years? _______ 1-2 year old males? _______ 2-3 year old males? _______ adult males? ________ will be added each time

Note: VORTEX has the capability to model even more complex demographic rates, if a user thinks that greater specificity is needed. For example, breeding or survival rates could be specified as functions of age. Contact Philip Miller, Program Officer with CBSG if you would like to learn more about this additional flexibility.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 3:
Kihansi Gorge

14-17 May 2007
Bagamoyo, Tanzania

CONSERVATION BREEDING SPECIALIST GROUP

UHURU NA UMOJA

WILDLIFE CONSERVATION SOCIETY

NATIONAL ENVIRONMENT MANAGEMENT COUNCIL MAZINGIRA

TOLEDO ZOO

The United Republic of Tanzania

The Lower Kihansi Environmental Management Project (LKEMP)

Consultancy to Conduct an Environmental Audit of the Lower Kihansi Hydropower Facility

Environmental Audit Report – Final Version

October 2005

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Environmental Audit Report - DRAFT

October 2005

Report no.	
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Checked	TNH/LMS
Approved	MIE

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List of Abbreviations

AgES	Agricultural Extension Service
AIDS	Acquired Immune Deficiency Syndrome
BOD	Biological Oxygen Demand
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMP	Catchment Management Plan
COD	Chemical Oxygen Demand
DG	Director General
DO	Dissolved Oxygen
DoE	Division of Environment (of the Vice Presidents Office)
EA	Environmental audit
EMA	Environmental Management Act
EAMCEF	Eastern Arc Mountains Conservation Endowment Fund
EMP	Environmental Management Plan
FBD	Forestry and Beekeeping Division (of Ministry of Natural Resources and Tourism)
HIV	Human Immunodeficiency Virus
IAP	Interested and Affected Parties
IDA	International Development Association
IREM	Immediate Rescue and Emergency Measures
JKT	Jeshi la Kujenga Taifa
KST	Kihansi Spray Toad (Nectophrynoides asperginis)
LKEMP	Lower Kihansi Environmental Management Project
LKHP	Lower Kihansi Hydropower Project
LWCP	Landscape Wide Conservation Plan for the Kihansi Upstream Catchment
masl	meters above sea level
MCH	Mother and Child Health
MSC	Multisectoral Steering Committee (LKEMP)
MTAC	Multidisciplinary Technical Advisory Committee
MUAJAKI	Participatory Public Health Project (acronym in Kiswahili)
MNRT	Ministry of Natural Resources and Tourism
MWLD	Ministry of Water and Livestock Development
NEMC	National Environmental Management Council
NORAD	Norwegian Agency for Development Cooperation
NPC	National Project Coordinator
NSSF	National Social Security Fund
PMU	Project Management Unit (LKEMP)
PRA	Participatory Rural Appraisal
RAMPO	Research and Monitoring Programme Officer
RAS	Regional Administrative Secretary
RBWB	Rufiji Basin Water Board
RBWO	Rufiji Basin Water Office
SEMAKI	Socio Economic Mitigation at Kihansi
SR	Safety Representative

STD	Sexually Transmitted Disease
TANESCO	Tanzania Electric Supply Company Limited
TASAF	Tanzania Social Action Fund
TAZARA	Tanzania-Zambia Railway
TAWIRI	Tanzania Wildlife Research Institute
TBA	Traditional Birth Attendant
Tsh	Tanzanian shilling
TPRI	Tanzania Pesticides Research Institute
VCT	Voluntary Counselling and Testing
VEO	Village Executive Officer
WCS	Wildlife Conservation Society
WD	Wildlife Division
WUG	Water User Group

Executive Summary

This report is the result of an environmental audit of the Lower Kihansi Hydropower Project (LKHP). The audit was conducted to assess whether the mitigation and monitoring measures identified under the Up-dated Environmental Management Plan (EMP) of the LKHP are achieving their intended objectives and to make future recommendations for the way forward. The EMP was formulated under the Lower Kihansi Environmental Management Project (LKEMP) in June 2004. The implementation period reviewed by this audit is therefore 14 months (June 2004 to September 2005).

The audit procedures followed are in line with the World Bank environmental audit guidelines and included standard steps of pre-audit, on-site audit and post audit guided by the audit protocol.

Audit criteria were derived from the EMP and agreed with the client during the pre-audit meeting. Since the EMP contains few quantifiable targets or indicators, the audit criteria are primarily a 'compliance check' verifying the extent to which the various monitoring and mitigation measures have been implemented to date. Physical field checks, however brief, allowed the audit team to comment on the efficiency of the various measures.

In addition, legislation and policies of key relevance were used for the assessment of compliance. These were in particular the 2004 Environmental Management Act, the 1974 Water Act, and the Tanzania Electric Supply Company Limited (TANESCO) 1995 Health and Safety Policy.

Based on the agreed audit criteria, checklists for the functional areas of the audit were developed to guide the collection of information and evidence by the various auditors. The findings form the functional areas provide the basis for this audit report.

An audit takes place during a short period of time and with limited resources. It is thus important to keep the inherent limitations in mind when using the audit results.

The principal findings of the audit are:

Gorge Ecosystem

- The sprinkler system is at the heart of the mitigation programme and thus is a most important aspect of the EMP. The fact that it is functioning, and that a team monitors and maintains the sprinkler system are indicative of the many positive aspects found. An Operations Manual has been formulated which guides the monitoring of the sprinkler system and related water quality monitoring in the Gorge. It follows the procedures of the EMP and the Gibb's 2004 monitoring protocol. There are some minor shortfalls, which need to be corrected.

- The construction of bridges, wooden stairways and stone walkways appears to have been effective from several points of view. These have improved the safety of all who visit the Gorge. The stone walkways in the spray wetlands appear to have reduced erosion on the paths. They also have made access in the wetlands much safer, and allow researchers and technicians to walk in the areas receiving spray without destroying the vegetation. The audit team noted some need for improvements to these structures.

- The impact of the sprinkler system on the ecosystem cannot be conclusively evaluated. The audit team found that on the upper and lower spray zone vegetation is regenerating, for example *Selaginella krausiana*. The current sprinkler zone covers a smaller area than the original spray zone and the unsprayed areas are transitioning into a dryer vegetation. The fact that no vegetation studies have been conducted since 2002 does not allow a systematic assessment of changes.

- The application by the Wildlife Division for the Water Right for the sprinkler abstraction has yet to be submitted. The present abstraction without a valid water right is not in compliance with the 1974 Tanzania Water Act.

- This audit was not meant to answer the question of survival of the Kihansi Spray Toad (KST). Nevertheless it should be noted that no KSTs were sighted during the on-site audit. However, others who have visited the Gorge in 2005 have seen one or two KSTs and the Gorge technicians heard toads calling.

- In context of the question of survival of the KST the prevalence and control of Chytrid fungi in the Gorge remains an important issue, which requires further attention. Further studies using a ‘swabbing’ technique on amphibians to monitor prevalence of Chytrids in the Gorge should be conducted.

- As long as safe reintroduction of the KST into the natural environment cannot be confirmed, the Captive Breeding Programme (CBP) must remain an important and on-going effort. Reports from the CBP should be analysed and made more widely accessible to interested parties. Verifying the feasibility of a national captive husbandry programme is an outstanding issue.

- The Kihansi scholarship programme by far extended the scope (qualitative and quantitative indicated in the EMP. In total two PhDs, ten Masters programme and 46 short-term training courses were supported. A shortfall of the MP is that it does not include any means of verifying whether or not this capacity building exercise is feeding into the knowledge base about the Kihansi Ecosystem and Biodiversity and Water Resources Management issues in Tanzania in general.

- While the focus was so far exclusively on high-level government and research institutions in Dar es Salaam, village communities and local government should be included as a target group into the scholarship programme.

Kihansi River Hydrology

- RBWO is fulfilling its role of monitoring the Water Right granted to TANESCO in June 2004 for abstracting water from Kihansi River for hydropower generation. This audit report contains several suggestions on how the RBWO monitoring functions could be further improved. These include ensuring that gauges and other equipment is working at all times, ideally through a resident technician based at the site.

- The bypass flow is a central issue of the EMP as it is of paramount importance to maintaining the ecosystem in the Gorge. The Water Right requires TANESCO to leave a bypass flow between 1.5 and 2.0 cubic meter per second. Based on RBWO reports and confirmed through an independent study commissioned by LKEMP, the current bypass flow at Kihansi indicate that 1.3 to 1.4 m^3/s is being released depending on the reservoir level. This environmental flow does not comply with the specifications made in the Water Right.

- During the time of the environmental audit, this deficiency was in the process of being rectified by TANESCO. An international consulting firm (NORPLAN) has been contracted to carry out an independent check of the LKHP to establish the causes of the reduced bypass flow and other possible design features that may have contributed to the violation of the final Water Right conditions. The work had commended and the final draft is expected for submission at the end of December 2005 or early January 2006.

- Monitoring of the dam by TANESCO needs improvement. Several dam monitoring tools, i.e. Piezometers, were not working. Furthermore, there is no standard procedure for monitoring of seismic events and stability of the dam. Reportedly TANESCO is in the final stages of engaging a Consultant of University of Dar es Salaam, Geological Department to investigate seismic events and come up with procedures of monitoring.

- Routine procedures for monitoring of sedimentation rate in the dam and release of sediments from the dam during flushing operation also need to be developed. According to TANESCO's comments on the draft audit report, LKEMP is responsible for the monitoring of sedimentation rate. Furthermore TANESCO commented that flushing operation is done mostly during high flow when there is spilling i.e. one of the big gates is always opened so some of sediments is taken out. The environmental auditors did not verify this on-site.

- A desk review of the TANESCO hydrological model revealed some inconsistencies, which need to be reviewed.

Erosion, Fire Control and Waste Management

- The present appointment of the Civil Technician responsible for environmental mitigation measures at the LKHP works site needs to be reviewed. The present staff responsibilities are inadequate to address the most pertinent issues as well as more medium and long-term environmental mitigation as specified in the EMP. In particular with regard to waste disposal some commitment and immediate action of senior management is required.

- While existing erosion control and re-vegetation measures have been successful there is no evidence that standard procedures or a control system are in place. The digging up of buried scrap metal from the construction phase, observed during the on-site visit is counter-productive to previous re-vegetation efforts and presents a safety and health hazard. Management action to prevent such uncontrolled activities should be taken. We understand that LKEMP has raised this issue with TANESCO.

- The prevention and control of fires is currently not adequately addressed by TANESCO and needs attention. Although reportedly some fire-breaks have been created around the LKHP site and awareness campaigns on fire prevention conducted, frequent fire outbreaks reveal that these measures are not adequate. During the time of the on-site audit a fire was observed, which broke out from one of the fields cultivated by TANESCO staff and was subsequently brought under control by the villagers. On 17 and 18 October 2005 another fire burnt down large areas of woodland within the LKHP project area directly adjacent to the Gorge Ecosystem. Urgent action is required by TANESO to implement a fire prevention and control plan. TANESCO should set a good example of management of its own land. In this context the legitimacy of cultivation of land by TANESCO staff on the fields directly adjacent to LKHP should be reviewed.

- The handling of solid waste at the LKHP works site lacks management and proper disposal procedures. The current practices pose health, safety and environmental risks and do not conform to the 2004 Environmental Management Act of Tanzania. In the comments provided on the draft Audit Report, TANESCO made the commitment that solid waste at the works site will be taken care of in 2006 and funds have already been set aside.

Occupational Health and Safety

- The occupational health and safety procedures at the Kihansi Hydropower plant are in substantive compliance with the January 1995 TANESCO Health and Safety Policy. Areas of deficiency are outlined in this report and need to be rectified. These include the tenure of the safety representative; the lack of a risk assessment programme; the lack of various measures required for emergency preparedness; the lack of availability of first aid and fire fighting equipment; as well as regular medical check-ups of staff and disease and accident reporting to the Ministry of Labour.

- Deficiencies noted pertaining to the overall safety management and control system are a lack of response from Headquarters to corrective actions suggested by the Kihansi safety representative; lack of clarity of institutional responsibilities with regard to occupational health issues; as well as lack of measures of pest control.

- Health and Safety issues that need attention in the Gorge refer to increased stability and safety of the suspension bridges; prevention of slipping on the wooden steps; improvement of the latrines in camps; as well as first aid and safety training. In addition some contractual issues were raised by the staff, which need to be reviewed by LKEMP.

Institutional Aspects

- The current monitoring and reporting practices are not fully in compliance with the arrangements foreseen in the EMP and may need to be reviewed. Some of the deficiencies might be an indication that the procedures outlined in the EMP were too complex in the first place and may hence need to be revised. Others refer to key elements of a monitoring system and would need to be rectified. These include for example the lack of an annual monitoring report summarizing all monitoring data collected in the Gorge Ecosystem and the implementation of a regular auditing cycle. Furthermore, the audit team notes that the EMP does not include any targets and indicators which makes monitoring difficult.

- Presently, there appear to be no institutional processes of data analysis and feedback into the system to ensure that mitigation and monitoring measures are adjusted according to the findings of studies and consultancy reports. This iterative process of implementation - monitoring – revision, is key to allow corrective action and lesson learning.

- Presently, the MSC and MTAC provide the coordinating bodies under the EMP. There are gaps with regard to full inclusion of all stakeholders of relevance to the LKHP and disclosure and dissemination of information. Concerns were raised in particular by Local Authorities and the RBWO.

- The long-term institutional responsibility and accountability for LKHP still needs to be clarified. Ultimate roles for mitigation and monitoring and the question of decommissioning need to be addressed. Presently, TANESCO is not building the financial reserves for decommissioning recommended under the EMP.

- The existence of a project to fund the monitoring and mitigation programme at Lower Kihansi seem to have flawed the need to make commitments by the responsible institutions. Such evidence was found in the Wildlife Division and TANESCO.

Socio-economic aspects

- There is poor continuance of activities initiated by the community programmes during the construction phase. District Governments bodies do not feel capacitated to assist here.

- Health issues are still an important area to be addressed, particularly HIV/AIDS and Malaria in both lowland and catchment villages. Similarly, community conservation and livelihoods activities initiated during the

LKHP construction phase need further follow-up. While the LWCP and the LKEMP small grants scheme include such activities for catchment villages, lowland villages are not included.

- There are ill feelings amongst the communities as expectations have not been met due to falsely raised hopes during feasibility and construction. Furthermore, transparency on the issue of land conservation was lacking since the construction phase. The frequent fires breaking out from land cultivated by TANESCO staff seems to aggravate the situation. There is no platform for community concerns in the operational phase of LKHP, which is a shortfall that TANESCO needs to correct.

- The LWCP is meant to address the community related problems outlined in this report. The main objective of the LWCP is to ensure joint conservation of the resource base through full and committed involvement of the communities in upstream areas. Although the auditors agree that the LWCP has the potential to, at least partly, remedy some of the ill feelings of the communities, the restriction of the LWCP on upstream villages leaves a gap with regard to the downstream villages. Since these villages are also part of the wider LKHP landscape this gaps needs to be addressed.

Part 1 – Introduction and Audit Procedures

1 Introduction

1.1 Background

An environmental audit of the Lower Kihansi Hydropower Facility was conducted by COWI Tanzania during the period of 13 June (contract signing) until 29 October 2005 (submission of final report) with a total input of 78 person days. The COWI audit team comprised of the following team members: Ms. Kerstin Pfliegner, Lead Auditor; Ms. Flora Ismail, Local Liaison Officer; Prof. Kim Howell, Ecosystems Analyst; Mr. George Sangu, Plant Ecologist and Sociologist; Dr. Charles Msuya, Animal Ecologist; and Mr. Exhaudi Fatael, Hydrologist. Ms. Maj Forum, on internship at COWI Tanzania, provided additional support to the team.

A copy of the Terms of References (TOR) is included in Appendix 1. A full list of people interviewed during the audit is in Appendix 2.

As defined in the World Bank Sourcebook, an Environmental Audit is a "*methodical examination of environmental information about an organization, a facility, or a site, to verify whether, or to what extent, they conform to specified audit criteria."(*The World Bank, 1995: 1). Audit criteria can be based on local, national and international laws and regulations, permits, or guidelines of organisations (The World Bank, 1995).

1.2 Objective

In the case of this environmental audit, the main objective was to assess implementation of the mitigation and monitoring measures specified in the updated Environmental Management Plan of June 30, 2004 (hereafter referred to as "*EMP*"). These requirements served as audit criteria. Additional audit criteria applied are listed in Section 2.2. below. The TOR, defined the overall objective of the audit as to:

"...assist LKEMP/Government to verify whether the environmental mitigation and monitoring measures recommended under the EMP are achieving their intended objectives of maintaining a sustainable eco-system in the Kihansi Gorge and its environs and recommend the best way forward".

1.3 The Environmental Management Plan

LKHP is a World Bank Category A project. Hence a full EMP is required to define mitigation, monitoring and institutional measures to address adverse social and environmental impacts associated with the development.

Mitigation and monitoring measures of the EMO relate to four geographical areas or systems within the LKHP:

- The Kihansi Catchment
- The Kihansi Gorge Ecosystem
- The LKHP Works Site and
- The Kihansi River.

A bi-annual audit is a monitoring requirement defined within the EMP. Therefore two would have been expected in the year 2004, however this audit is the first one conducted under the EMP.

1.4 Structure of the Audit Report

The remaining Sections of Part 1 of the report describe the audit procedures. Part 2 of the Report will present the audit findings. Socio-economic aspects in the context of LKHP are described in Part 3, and finally recommendations and conclusions in Part 4 of the Report.

Part 1 will first present the scope and purpose of the audit (Section 2.1), then the audit process followed (Section 2.2) and finally the criteria applied (Section 2.3).

The audit findings presented in Part 2 of this report are structured according to the functional areas that formed the scope of this audit. Table 1 below shows how they relate to the four areas of the EMP.

Table 1 Audit Functional Areas and EMP Systems/Areas

Functional Area of Audit	**Chapter in audit report**	**EMP System Area**
Gorge Ecosystem Analysis, incl. sprinklers, infrastructure, amphibians,	3	Kihansi Gorge Ecosystem
Vegetation	4	Kihansi Gorge Ecosystem
Hydrology	5	Kihansi River
Control of erosion and wildfires, waste management	6	LKHP Works site
Health and Safety	8	Not covered in the EMP
Institutional Aspects	9	Chapter 7 EMP

The review of socio-economic aspects in Part 3 of the report is aligned with the structure of the Landscape Wide Conservation Plan (LWCP) for the Kihansi Upstream Catchment.

Recommendations for follow-up and rectification are presented throughout each Chapter of the report and have been summarised in Part 4.

2 Audit Procedures

2.1 Purpose and Scope of the Environmental Audit

Based on the TOR and the discussions with the Client, the Consultant understands that the purpose of the Environmental Audit of the LKHP is to provide a 'snapshot' of the environmental situation at the project site by

a) assessing the implementation of the EMP against its own stated requirements; and

b) making recommendations for corrective action, where needed.

The scope of the EA included all mitigation and monitoring measures identified under the EMP. In addition, the TOR required the audit team to conduct a health and safety audit, which was to cover TANESCO operations at the Hydropower facility, as well as LKEMP operations within the Gorge.

The Auditors could not undertake the review of cost estimates provided in the EMP and make recommendations for financial management procedures as required in the TOR. This is because financial information was not made available to the Auditors.

The audit team was also requested to review any on-going mitigation measures that started under the IREM project. The IREM project was put in place as an environmental emergency project under TANESCO to cover a bridging period (2001) during which a broader, long-term plan would be developed; which is the EMP. The most immediate and obvious adverse environmental effect of the abstraction of water by the LKHP for power production was the drying out of at least 80% of the spray wetland habitat required by the Critically Endangered Kihansi Spray Toad (KST). As such, the IREM components have formed the basis for many aspects of continuing the management and conservation of the Kihansi Gorge Ecosystem under the EMP.

As agreed with the client during the contract negotiation meeting, consultations with representatives of selected communities were to be included in the scope of the audit to get a comprehensive view of the environmental situation at and around the site, in particular because local health and safety hazards were identified as potential impacts of the project. However, since social and health related mitigation and monitoring measures are not included in the EMP no audit criteria could be derived from the EMP. Therefore, it was hence agreed with the Client that the main purpose of the social audit was to get a general overview on how villagers are affected by the hydropower project and to provide a ‘crude’ assessment as regards to the sustainability of activities funded under the community based programme of the LKHP construction phase; namely Participatory Public Health Project (MUAJAKI), Socio Economic Mitigation at Kihansi (SEMA-ki) and the Catchment Management Plan (CMP). The social component of the audit is not to be confused with an evaluation of these programmes.

As per TOR and agreed with the client in the Pre-audit (Inception) meeting, the scope of the environmental audit is therefore as described in Table 2 below:

Table 2 Scope of the Environmental Audit

Area	**Detail**
Organisational	• Within the scope of the EMP • LKEMP/TAWIRI, Kihansi and Dar es Salaam • TANESCO, Kihansi and Dar es Salaam • RBWO, Iringa • One selected Local Authority; i.e. Mufindi District • Wildlife Division, Dar es Salaam • NEMC, Dar es Salaam
Time	• 14 months implementation period of EMP June 2004 to September 2005 • In addition any on-going mitigation measures that started under IREM: ▪ Sprinkler ▪ Access infrastructure, walkways etc. ▪ Captive breeding To be evaluated for their entire duration.
Functional	• Vegetation • Vertebrates, amphibians • Hydrological (by-pass flow, sprinkler system, implementation of Water Right by TANESCO) • Socio-economic and public health • Occupational Health and Safety • Institutional (Operational set up of EMP; site management; research programme, Kihansi Scholarship)
Compliance Hierarchy	• Compliance with EMP requirements • National Laws and Regulations • Standards • Policies • Guidelines and Procedures • International Conventions (Biodiversity Convention, CITES)
Locational	• TOR: ▪ Kihansi Gorge ▪ ”Its environs”: Area west of the Kihansi River owned by village government and Area east of the Kihansi River within Njerere Forest Reserve

Area	Detail
	• Contract Negotiation: ▪ Upper Catchment Area: Social and public health issues in 2 villages (Uhafiwa and Ukami) ▪ Lower downstrean Area Social and public health issues in 3 villages (Mlimba, Kalengakelu, Udagaji)
	• EMP Focal area: ▪ LKHP works site (with regard to revegetation, waste management, Health and Safety) ▪ Kihansi Gorge (with regard to LKEMP activities) ▪ Kihansi River (upstream Uhafiwa village, downstream Tailrace focus on Hydrology and Water Quality)

2.2 Audit Process

The environmental audit was conducted according to systematic procedures and focused on verifying if the mitigation and monitoring measures specified in the EMP conform to the planned arrangements. The assessment relied on professional judgement of the auditors, their objectivity, and physical verification of the findings.

The environmental audit used primarily existing information and reports produced under LKEMP, interviews with staff, and personal observation at the site. Spot checks in the form of samples were included with regard to the water quality monitoring system and the sprinkler system to verify that equipment is operational and in compliance with requirements of the EMP and to triangulate information obtained through interviews.

Actual measurements, counts and physical tests, for example for water quality, turbidity, sedimentation, toad or vegetation counts were not conducted during the on-site audit. These would by far extent the time frame of an audit. The focus was rather to verify whether the tests and studies had been done according to the plans and management action taken with regard to the obtained results.

The process of the audit followed insofar as possible standard auditing procedures adjusted to the specific requirements of this particular audit and the client's needs.

The process was divided into three phases: pre-audit, on-site audit, and post-audit. An overview of the process followed is provided in Table 3 below.

Table 3 Audit Process

Phase	Activity
1. Pre-audit	Mobilize team and assign auditors
	Review of existing documents
	Formulate audit criteria
	Design checklists
	Prepare audit protocol (Inception report)
	Pre-audit (inception) meeting with the client

Phase	Activity
2. On-site audit	Site visit and consultation with relevant site personnel
	Conduct checklist audits in agreed functional areas
	Hold daily team meetings
	De-briefing of the site representatives of LKEMP and TANESCO
	Follow-up Meetings with EMP implementing agents based on Dar es Salaam, i.e. LKEMP; TANESCO; NEMC and Iringa Region, i.e. RBWO; Mufindi District Council.
	Short progress report to the client and data analysis
3. Post-audit	Team meetings to discuss audit findings and recommendations
	Data analysis and report writing
	Final report after comments from Client

2.2.1 Pre-audit

During the pre-audit phase, two consultants were assigned for the various functional areas of the audit. Appendix 3 contains the names of professional auditors and their area of responsibility for this audit. Each auditor was provided with a list of relevant documents for his/her respective technical area to review. A small temporary library was established for this purpose in the Consultant’s office, which ensured that all team members had access to the documents and a working space. A full list of documents reviewed and references used is in Appendix 12 of this report.

After the review of documents, audit criteria were formulated and checklists designed and discussed in team meetings to ensure cross-reference between the various technical areas. A full set of checklists is provided in Appendix 4. The checklists provided for a systematic assessment during the on-site audit but did not restrict the auditors from exploring aspects not covered in the checklist.

The audit protocol was prepared to guide the audit process. It included the list of documents and compulsory reading for each auditor, a time schedule and a work plan. A copy of the audit protocol is included in the Inception Report.

A pre-audit (inception) meeting with the client was held on 5 September 2005 to clarify the objectives and scope of the audit, agree on the audit criteria and procedures and to finalize staffing and logistical arrangements. Minutes of the meeting were included in the Inception Report.

2.2.2 On-site audit

The on-site audit was over an elapsed period of six days (including travel) during which the team visited Kihansi. The itinerary and the plan for field operations showing division of labour and timing is provided in Appendix 5.

The on-site audit at Kihansi started with an opening meeting with the Acting TANESCO Plant Manager and the LKEMP Research and Programme Monitoring Officer (RAMPO). During the meeting the audit team was introduced, objectives, scope and criteria of the audit described and a work schedule based on the preliminary field plan agreed upon. The RAMPO acted as the main contact person during the on-site audit.

The meeting was followed by a tour of the site and areas subject to the audit to familiarize the audit team with the location and activities. Care was taken by the audit team to disrupt routine activities as little as possible and provide for a relaxed atmosphere during the interviews.

Audit findings were discussed amongst the audit team on a daily basis and the strategy for the next day planned. The team remained in constant touch by cell phone during the on site audit.

The on-site audit closed with a de-briefing meeting with the same people as the opening meeting. Results were presented in the form of main findings, split into good practice and non-conformities, as well as intended recommendations for corrective action to be included in the audit report. The closing meeting provided feedback on the results and some immediate management commitment for the corrective actions suggested by the audit team to the TANESCO plant manager and the RAMPO.

2.2.3 Post-audit

As part of the audit but subsequent to the on-site audit in Kihansi, additional meetings were conducted with TANESCO and LKEMP Headoffices in Dar es Salaam as well as the National Environmental Management Council (NEMC). Visits to the Rufiji Basin Water Office (RBWO) in Iringa and Mufindi District Council were also undertaken. The purpose of these visits was to complete the respective sections in the checklists that referred to those institutions and to close information gaps that emerged during the on-site audit.

A progress report (COWI, 27. September 2005) and the final audit report were prepared during the post audit phase.

2.3 Audit Criteria

The audit team collected information and documented evidence based on agreed audit criteria. The main criteria are compliance with the mitigation and monitoring measures listed in the EMP. This audit was conducted to assess whether and to what extent the various measures have been implemented successfully. The measures are listed in Table 4 below.

Table 4 Areas of Mitigation and Monitoring in the EMP

Area of Mitigation & Monitoring	Pages in EMP	Aspect to be assessed
Catchment	57 onwards and 76	• Human Health • Natural Resources Management • Water Resources Management and

	onwards	Abstraction • Awareness and Enforcement • Employment and Local Communities
Kihansi River	61 and 78	• TANESCO Water Right • Its monitoring and related reporting
Gorge Ecosystem	64 on-wards and 80 onwards	• Sprinkler Systems • Fountain Jets and Alternatives • Maintenance Infrastructure • Ex Situ Captive Breeding Programme • Kihansi Scholarship
LKHP Works Site	72 on-wards and 88 onwards	• Environmental mitigation measures • Fire prevention • Revegetation and prevention of land slides • Prevention of siltation of the dam • Curbing grazing on steep slopes • Social mitigation measures • Malaria prevention • General health programs • Sports events • Provision of Mlimba water supply • Solid waste management programme • Community relations programme
Environmental Impacts of Miti-gation Measures	72 on-wards	• Reduced wilderness • Visual impact of artificial sprinklers • Erosion by fountain jets • Accidental disease introduction • Studies on alternative water sources to substitute bypass flow
Monitoring of various habitats	81 on-wards	• Spray wetlands • Forests • Spray Toad • Temperature & Humidity monitoring
Monitoring of water quality in the Gorge	86 on-wards	• Monitoring system in place to assess changes and enable rapid response • Provide information to identify cause and source of threats • Sediments; turbidity; BOD; COD; organic and inorganic substances to be measured by LKEMP field staff

For each of the measures listed in the EMP the audit team assessed the

- Status and progress of implementation;
- Results and efficiency of the measures;
- Institutional communication and follow-up actions; and
- Existence of physical evidence.

Additional audit criteria were compliance with the following policies, laws and conventions:

- The 1995 TANESCO Health and Safety Policy;
- The 1974 Water Act;
- The 2002 Tanzania Water Policy;
- The 2004 Environmental Management Act;
- The International Convention of Biodiversity; and
- CITES.

The audit findings are presented in the following chapters in Part 2.

Part 2 – Audit Findings

3 Kihansi Gorge Ecosystem

This Chapter provides a detailed overview of the assessment of performance against the mitigation and monitoring measures outlined in the EMP for the Kihansi Gorge Ecosystem from page 64 onwards and page 80 onwards respectively. The assessment was conducted against the relevant checklists in Appendix 4 to verify the implementation progress; highlights strengths and weaknesses and identifies 'gaps' or areas of 'non- compliance'. Areas of 'non-compliance" have been defined as activities that deviate from the planned activities in the EMP or areas that have not been implemented. In addition the audit team was asked to review the implementation of recommendations made under IREM. A table comparing the main IREM recommendations and audit findings regarding their implementation is included in Appendix 6.

3.1 Artificial Spray System

The artificial spray system consists of sprinklers in the upper, lower and mid wetlands as well as fountain jets in the upper wetlands. IREM studies recommended ensuring that the artificial spray systems are fully operational and that a minimum bypass flow of at least 1.5 m^3 is continuously operated to maintain the spray wetlands ecosystem. The sprinkler system is a core element of the EMP and as such particular attention should be paid to it to ensure that is functions well at all times. This has been achieved by the maintenance system that has been established. It is described below.

3.1.1 Maintenance

Seven technicians are employed by LKEMP to maintain the artificial spray system in the Gorge. NORPLAN staff trained these technicians when the system was installed. The technicians work under direct supervision of a Head Technician and overall guidance of the Research and Monitoring Programme Officer (RAMPO). The RAMPO, a Tanzania Wildlife Research Institute (TAWIRI) employee, is permanently based at Kihansi to manage and coordinate the Gorge mitigation and monitoring program.

Overall, we found that the routine maintenance practices carried out by the Gorge technicians are in compliance with the measures described in the EMP and the TANESCO "*Instructions for the Maintenance of the artificial spray system in the Kihansi Gorge*" developed by NORPLAN in 2002, referred to by the technicians as '*the manual'*.

The manual includes a standard maintenance form, which is filled regularly by the technicians and forwarded to the RAMPO. This routine check includes the sprinklers in the mid-gorge, lower and upper wetlands; the filters; elevated basin; the intakes and the fountain jets.

Daily patrols are conducted to ensure that the sprinkler system is operating and also to check for intruders in the Gorge. Daily reports with all details (for example replacement of sprinklers, any intruders etc.) are made in a logbook with waterproof paper, referred to as '*the logbook*". In case of any problems, the Gorge attendants fix the problem immediately themselves, or if they are unable to do so, they report the problem to the RAMPO for follow-up.

In addition, a systematic survey of the whole area is undertaken three times per week during which the maintenance form for the artificial sprinkler system is filled. The routine maintenance activities carried out are listed in Box 1 below.

Box 1 Routine Maintenance Activities

Routine Maintenance carried out on the Artificial Sprinklers

- Cleaning of nozzles after inspection;
- Checking of pressure and nozzle erosion;
- Replacement of nozzles;
- Pressure check on each sprinkler line with a pressure gauge at least three times per week;
- Cleaning of sedimentation ponds with tools and shovels, frequency depends on visual inspection;
- Cleaning of filters in sedimentation ponds; and
- Pipes from ponds to sprinklers systems checked for damage etc. during daily patrols and problems repaired through routine maintenance.

The two fountain jets were installed in December 2001. Due to erosion problems they are currently aimed at the river channel instead of the Upper Spray Wetland where they caused erosion and removal of vegetation. Maintenance (unclogging) of the Fountain Jets is carried out as part of the overall Gorge maintenance system.

Based on our interviews with LKEMP site staff and physical verification through records as well as site visit, the sprinkler system and fountain jets were working properly during the time of the audit. The assessment of the artificial spray system by the audit team is presented in Table 5 below.

Table 5 Assessment of the Artificial Spray System

Spray Zone	Findings
Mid Gorge spray wetlands	• Working properly • Flow 1.3 l/s – max pressure in pipes 6.2 bars • Cleaning is done when pressure drops below 4.5 bars • Almost all 42 nozzles are replaced in 3 months, especially in rainy season. • Source of water is Handaki stream
Lower spray wetland	• Working properly • Flow 2.5 l/s and max pressure 7.2 bars • Cleaning is done when pressure in the upper spray wetland is between 3.4 and 3.6 bars • Replacement of between 1 to 3 out of 84 nozzles in 3 months • Source of water is Kihansi river (by-pass flow) and Jabali stream
Upper spray wetland	• Working properly • Flow is 6.4 l/s and max pressure 4.2 bars • Cleaning is done when pressure drop is between 3.4 and 3.6 bars • Replacement of up to 10 out of 250 nozzles in 3 months • Source of water is Kihansi river (by pass flow) and Jabali stream
Jets	• Small jet gets water from 2 HDPE pipes 3 inch • Big jet gets water from 4 HDPE pipe 3 inch • Source of water is Kihansi river (by-pass flow)

The different quantity of nozzles that need replacement in the different spray zones is related to amount of sediment in water; the more sediment, the higher the frequency of replacing the nozzles due to fast wear out of the plastic nozzles. The rate of replacement is the highest in the mid Gorge because the water from Handaki stream is only filtered through a mechanical filter. These filters are expensive but not very effective. The Upper Spray zone gets water from Jabali intake and goes through a sedimentation tank first. Here the rate of nozzle replacement is lower than mid Gorge. The same water is going to another elevated basin, which acts like a second sedimentation tank before going into the lower spray zone sprinklers. This double tank system seems most effective in reducing the rate of nozzle replacement to only 1-3. The result is better water quality and better flow of water out of the sprinklers.

The audit team recommends the following issues for follow-up and/or rectification:

→ Introduction of a double tank system for all three spray wetlands may reduce the need for mechanical filters. The cost of one mechanical filter is about Tshs 3 mill. and replacement is difficult as they need to be imported. For the same amount a good sedimentation tank could be built.

→ Fountain jets: The pressure is not measured and they have no filters. This is acceptable under normal circumstances but can become a problem during the long rains and if there is a big release of water from the dam. Hence, measurement of pressure and installation of filters would be advisable.

→ Supply of spare parts: The technicians noted that there is delay to get spare parts, sometimes even to obtain a simple item like a cock (tap), electric drills etc. Therefore, the procurement procedures should be improved to allow the RAMPO to hold a cash fund (imprest) to cover such expenses, or manage a checking account for such contingencies.

→ Flow metres as listed in the EMP were never installed. However, the pressure checks are used as an indirect method of assessing flow. These pressure checks on each sprinkler are a useful measure, as a drop in pressure indicates a nozzle or other blockage. This activity may be done more often during the rainy season.

→ The EMP indicates that the cleaning of sedimentation ponds should be done every 2-3 weeks. Based on our physical inspection, this should be done more frequently.

3.1.2 Further Studies

The EMP mentions that two further sprinkler studies are to be undertaken: A study on tandem sprinklers as back-up and a study to reduce vulnerability to the piping system. The EMP foresees further trials by varying the size of fountain jets, change of angles etc.

We were informed that NORPLAN was awarded a contract to undertake these studies. The TOR of the assignment include also a mini catchment study to review the hydrology of new sources of water, options for backing up the existing sprinkler system, upgrading and maintaining the existing one and ecological considerations related to the proposed options.

The planned study on alternatives to the fountain jets is also part of the NORPLAN sprinkler study mentioned above.

The EMP further mentions that '…*expansions [of fountain jets] offers perhaps the best opportunity for provision of some mitigation in adjacent wetlands*". So far no expansions have been planned. Based on information by the LKEMP office in Dar es Salaam, expansion of the mitigation activities in adjacent wetlands is part of the same NORPLAN consultancy.

A complex issue directly related to the possible extension of the sprinkler system is the question about the source of water. Although the bypass flow from Kihansi River, combined with the flow from Jabali and Handaki streams, are presently sufficient to operate the sprinklers, a future expansion of the system would need to take into account how it would affect the bypass flow or flow from other, additional sources. This issue has equally been raised in the NORPLAN Sprinkler back-up study.

The Consultant team has the following recommendation with regard to the Gorge infrastructure:

→ Should the Gorge infrastructure be extended in the future based on the results of the studies on the sprinklers and fountain jet regime, there is a need to be budgeted for this possibility. The question of the water sources of the extension will need to be investigated with care. The current by-pass flow should not be reduced further.

3.1.3 Sprinkler Flow, Water Source and Water Right

The EMP mentions the bypass flow, and small tributaries to Kihansi without further specification, as the source of water for the Artificial Sprinkler System.

As specified in the NORPLAN Drawing No. 100-01 and confirmed during the on-site audit, these tributaries are Jabali stream for the Jabali intake feeding into the upper and lower spray zone, and Handaki Stream for the mid Gorge wetland.

We were unable to confirm the exact abstraction of water for the spray system and the sprinkler flow in terms of output. The EMP mentions "…*about 10 litres/second*". We were also unable to establish if there is an even distribution of precipitation across the spray zone. It seems that this would be important information to establish the efficiency of the artificial spray system.

During the IREM studies, experiments were undertaken on sprinkler and flow manipulations to assess which increase, decrease, amount of bypass flows etc. worked to meet the spray demands. The EMP notes that "for now" sprinklers are to be maintained as is (p.71). This raises the question on what would be a trigger for change? There is a need to monitor sprinkler precipitation.

According to the EMP a separate Water Right was to be obtained for the abstraction of the water feeding into the artificial spray system. This falls under the responsibility of the Wildlife Division. We were informed that this Water Right has not yet been applied for. Although representatives of the Wildlife Division (WD) agree that it falls within their mandate at Kihansi we were informed that application for Water Rights is an activity where the WD has no prior experience. We were told that the application for the Water Right is not relevant during the lifetime of the project and will be dealt with after the project has expired and will be institutionalised.

The audit team recommends the following issues for follow-up and/or rectification:

→ The current water abstraction for the sprinklers and fountain jets without valid Water Right is illegal and the WD should abide with the Water Act of 1974 Section 15.

→ Studies on spray system output and distribution need to be conducted.

→ Additional intensive monitoring of the spray input in the upper wetland ecosystem has not yet been effected as foreseen in the EMP and should therefore be prioritised.

3.2 Gorge Maintenance Infrastructure

Infrastructure has been established at some places in the Gorge and includes bridges, ladders, small shelter for Gorge technicians and a campsite. These structures are inspected and maintained by the Gorge attendants on a daily basis. Records are kept in the logbook.

There is also off-site infrastructure, comprising storage and facilities for spares and monitoring equipment. An indoor work area, office and housing for the maintenance team has also been established. The planned UHF radio network is present and its operation has been verified by the audit team in the office and in the Gorge at the Upper Spray Wetland Station. The vehicle is in working order.

The audit team recommends the following issues for follow-up and/or rectification:

→ During the physical inspection of the Gorge maintenance infrastructure some safety concerns arose. These are outlined in Chapter 7 of this report and recommendations for corrective action is made.

→ The construction of the research station planned in the EMP for 2004 has not yet been built. According to the March 2004 – March 2005 progress report, a contract with the Civil Works consultant was signed 29 September 2004. We recommend that an EIA be undertaken prior to the completion of the design.

3.3 Habitat Monitoring

As foreseen in the EMP, TAWIRI is carrying out the monitoring of various habitats within the Gorge Ecosystem through the RAMPO, who is a TAWIRI employee, seconded to LKEMP.

The basis for habitat monitoring is laid out in the IREM reports, which note that it is important to continue monitoring the various aspects of the Kihansi Gorge Ecosystem, including the Spray Toads, vegetation, insects and micro-climate so as to detect changes and trends. Methods have been laid down in Gibb's 2004 Monitoring protocol.

We were able to confirm that the habitat monitoring largely follows the procedures described in Gibb's protocol, IREM and the EMP - with some gaps. Our detailed assessment is presented in Table 6 , which is reproduced from the EMP (p. 85).

3.3.1 Kihansi Spray Toad Surveys

With regard to the Kihansi Spray Toad (KST), IREM recommended that monitoring be conducted 4 times annually, in January, March, June and October over the next 3-5 years. Because the counts used by IREM appeared to be damaging the vegetation, rock plot counts were suggested instead of counting the toads along vegetation transects in the wetlands. Control areas were established. These areas that were previously bare rock have become covered with vegetation, including the stainless steel markers. To ensure continuous monitoring the position of the bolts marking the plots needs to be visible.

The KST counts conform generally to Vol. III IREM report with a few exceptions:

- Daytime permanent rock plots have been established but are not maintained;
- Plots along the vegetation have been established but not always monitored;
- There is a standard sheet available to the team but are not always filled;
- Counts in spray wetlands are undertaken.

We were informed that due to the occurrence of ‘all zero counts” the systematic counts have been replaced by opportunistic searches, which means that forms were not filled and not every plot may have been checked to make sure of a negative count. Consequently the data will not be there to analyse, unless one assumes a zero count for all plots.

During the on-site audit, no toads were sighted.

An issue to consider is that if the toad recovers, this might be a unique case in which the continued existence of species is entirely dependent on a simple, gravity fed sprinkler system that requires constant attention and maintenance.

The survival question of the KST has been linked to the spread of *chytrid* fungus in the Gorge. The LKEMP office in Dar es Salaam reported that in 2005 a study was commissioned on *chytrid* fungus.[1] The study has revealed the presence of the fungus in the samples collected. However, such information was not available on site.

With regard to the *chytrid* fungus, it is important to note that there is a protocol for sampling chytrid on amphibian skins just by taking a swab. The frog does not have to be killed to cut up its skin. This would be suitable in the Kihansi context.

If KSTs have survived, the question of whether these survivors have become or were resistant to the fungus, or if the fungus became less virulent, or simply less abundant after the outbreak, is of direct management relevance to Kihansi and also of global importance. We therefore recommend that a protocol be established and implemented for the toads, which are detected, as well as other amphibians in the Gorge. This example illustrates the importance of LKEMP not acting in isolation and to have scientific links and partnerships. It is through those that technical ability will be built up that might help to solve scientific management problems.

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[1] Weldon Che, 20 May 2005, Chytridiomycosis Risk Assessment in the Kihansi and Udagaji Gorges with special reference to the KST, Final Report.

3.3.2 Precipitation measurement

Natural precipitation is measured daily but the frequencies had to be reduced from daily to weekly. Gauges distant from the falls are measured twice per day (8am and 4pm) and gauges close to the falls 3 times per day (8am, 12 pm and 4pm). In addition to natural precipitation, the artificial precipitation generated by the sprinkler system needs to be monitored according to Gibbs monitoring protocol. This had not been done but was introduced as a result of the on-site audit (based on personal communication with the RAMPO on 4. October, the measurement started on 19. September 2005).

Table 6 Assessment of Habitat Monitoring Activities

As per EMP		Results of on-site audit	
Variable	**Frequency**	**Findings**	**Responsible**
Physical Charactaristics / Sprinkler System Operations			
Precipitation (mm)	Daily	We were unable to confirm. Whereas one person said yes, another said in the upper spray zone only. Measurements written in logbook, transferred to computer by RAMPO.	LKEMP
Kihansi River Discharge (m^3/S)	Daily	Is measured (report from the power house)	TANESCO
Air temperature (C^o)	Daily	Yes. Dataloggers present. Logger downloaded at varying 3,2, 1.5 months intervals. Problem with logger, must be moved to office to download data.	LKEMP
Wind speed (km/hr), 1 site	Continuous	Not measured.	LKEMP
Water Temperature (C^o), 2 locations	Daily	On weekly basis as reported by RAMPO	
Relative Humidity (%), 1 site	Daily	Not measured. Technical problem. Readings all one figure, constant.	LKEMP
Sprinkler system Flows (liters/s)	Continuous	Not measured. No suitable gauge. Pressure is monitored and forms a kind of indirect measurement of flows	LKEMP
Sprinkler System Water Temperature (C^o)	Daily	Yes. Weekly. Gauge present. Data verified on data sheets.	LKEMP
Kihansi River Water Temperature (C^o)	Daily	On weekly basis. Every Friday. Started in April 2005.	LKEMP
Sprinkler System Water pH	Daily	Is measured once per week as part of the routine water quality monitoring.	LKEMP
Kihansi River pH 2 sites	Daily	On weekly basis	LKEMP
Sprinkler System Water Conductivity (μ-ohms/s, two sites)	Daily	On weekly basis	LKEMP
Kihansi Water Conductivity (as above)	Daily	On weekly basis	LKEMP
Soil Moisture mbar (10/wetland)	Daily	Not measured. No capacity on site to do so.	LKEMP
Erosion deposition around soil cracks: mm/month, 25/wetland	Monthly	Not measured.	LKEMP
Suspended Solids/sediment/turbidity of Kihansi River flow through Kihansi Gorge; 2 sites	Daily/Continuous	On irregular basis. No regular monitoring.	TANESCO
Suspended Solids/sediment/turbidity of applied sprinkler system water, 2 sites	Daily/Continuous	Not measured. Technical problems, turbidity meter not functioning.	LKEMP
Droplet density, size, 1 site	Monthly	Not measured. Lack of capacity. Needs training.	LKMEP

As per EMP		Results of on-site audit	
Variable	**Frequency**	**Findings**	**Responsible**
Biological Monitoring			
Wetland Vegetation Characteristics – Species composition and coverage	Annually, using IREM techniques	The planned annual monitoring of wetlands towards the end of the dry season using protocols devised by IREM and elaborated by Gibbs (2004) are not being conducted regularly. The last report dates 2002. Another monitoring study is expected to take place this year.	LKEMP
Kihansi Spray Toad Surveys – IREM and the Panel of Expert Monitoring Techniques	2-5 times/yr	Measured through daily observation. Rather informally. Reports verified. RAMPO holding data sheets. Any toads noted in logbook. RAMPO reports to head office. Toad surveys were being conducted during World Bank Supervision missions in April and September 2005. See more comments in text.	LKEMP
Remote Imaging/Aerial photography/ multispectral digital satelite imagery, to evaluate vegetation/land use and land cover changes over time	Once, repeated every 5 years	First aerial photograph done in 1999 to set baseline for vegetation and land use. Second aerial survey was done in 2003 under LKEMP for the preparation of the LWCP. Compared changes to 1999. We were unable to confirm if future images are planned to allow systematic assessment of changes in a 5 year cycle.	NEMC/ LKEMP
Forest Woody Vegetation Characteristics – Kihansi Gorge and Udagaji Gorge PSP re-measurements; 28 sample plots: 20 in Kihansi Gorge, 8 in Udagaji. This program includes monitoring of the endemic plant species in the Gorge	Annually	❑ Irregular monitoring due to contractual difficulties and specialist availability; ❑ Last monitoring study in 2002 (Taplin & Ndangalasi) ❑ Consultant contracted for monitoring study in October 2005	LKEMP
Epiphylls (50 leaves per woody vegetation plot)	Annually	Not monitored. Epiphylls monitoring is included in TOR of forthcoming vegetation study. However, no baseline and protocol established.	LKEMP
Dipterans, in the wetland vegetation communities; no pupae and adults, 5 plots per wetland	Annually	Has been done once by Mweka African Wildlife College. From June 2004 to June 2005.	LKEMP

3.3.3 Water Quality Monitoring

LKEMP is presently responsible for the monitoring of water quality in the Gorge. We found that the RAMPO and Gorge Technicians are familiar with the "*procedures to follow in case of sudden changes of water quality*", outlined in Appendix 8 of the EMP. Reportedly such a case has so far never occurred.

Field-testing of water quality is coordinated with the overall maintenance program of the Gorge. Indicators tested include Dissolved Oxygen (DO), pH, Conductivity, Turbidity, Temperature, and Salinity. The water testing includes samples from sprinkler system water sources, the dam, and the Kihansi River as foreseen in the EMP.

One of the Gorge technicians has been appointed to fill all measurements into standard forms. A water quality testing metre is used to perform the water quality measurement. Some samples are taken to Tanzania Pesticides Research Institute (TPRI) for further analysis. Pressure measurements are undertaken at the mid Gorge and upper gorge.

The Operations Manual (see section 3.3.1. above) foresees that water quality checks are performed three times per week (Mondays, Wednesdays, Fridays) but it is only practiced once per week (every Friday). This timing was chosen so that the water quality monitoring coincides with the inspection of the spray equipment i.e pipes, joints, valves and nozzles. Although the Manual is not followed, the audit team believes that weekly checks are sufficient and it is hence not an area of concern other than that the manual should be revised to reflect this change.

Ten Data loggers were installed, data from which are downloaded once per month, providing information on time, day, relative humidity (%) and temperature (degree C). Physical inspection revealed that only six out of the ten data loggers are working. The data loggers at Mhalalala and two at mid Gorge are broken.

There is no routine water quality monitoring for organic substances, BOD , COD etc. as foreseen in the EMP. However, as we were informed by the World Bank comments on the draft audit report, a toxicological survey was conducted by LKEMP with the objective to establish the level of pesticides residues at the gorge and its catchment area. This survey was meant to help understand the extent to which these agro-chemicals impact the biological and ecological integrity and diversity of the area. Another objective of the survey was to establish whether or not pollution of the water source through agricultural practices and economic activities may have contributed to the crash of the KST population.

The audit team recommends the following issues for follow-up and/or rectification:

→ No specific training of the Gorge Technicians has been conducted for monitoring of water quality. The head technician has a background in automobile mechanics and would need further training on hydrological and ecological basics.

→ The RAMPO is competent to evaluate the monitoring data that is being collected at site but is not empowered to make use of the data to change operations or make necessary adjustments without authority from LKEMP Dar es Salaam. This is delaying adjustments and the authorities granted to the RAMPO may therefore need to be reviewed.

→ Representatives from TPRI, TAWIRI, and the University of Dar es Salaam have been at Kihansi to take samples of soil, water and sediments but reports of the findings have not reached the RAMPO office. This should be rectified as quickly as possible.

→ Turbidity cannot be measured, as the water quality checker is not working. The water quality checker should therefore be repaired.

- → Sediments, BOD, COD, and bio-monitoring, i.e. levels of phytoplankton are to be tested in regular intervals. Apart from one toxicological survey there is currently no routine monitoring of organic substances used as pesticides or fertilisers. Provisions for testing and monitoring should be made.
- → When the first two data loggers broke, they were sent to Dar es Salaam in April 2005 for repair. There was no follow-up. Later, another two were broken and they are at the site. Action to repair and replace data loggers is therefore highly warranted.

3.4 Gorge Access and Safety Protocol

The EMP requires that the number of visitors to the Gorge is kept to a minimum. It is limited to mitigation and monitoring teams and study teams and others visiting Kihansi on official business and with permission of NEMC, TAWIRI or WD. Tourism is presently not promoted.

The audit team was given different information about access to the Gorge from different sources. At the site we were told that access to the Gorge is controlled by LKEMP through Dar es Salaam and the RAMPO on site. Permission of access is usually obtained in person or by letter from the LKEMP Project Coordinator, sometimes by phone or fax. TANESCO in Kihansi refers access to the Gorge to LKEMP. The LKEMP office in Dar es Salaam informed us that access to the Gorge is obtained through an access permit from NEMC and TANESCO.

It appears that a procedure to obtain access to the Gorge has not been adequately communicated, which may lead to confusion. This was confirmed by the RAMPO who reported that there is a problem as people usually do not know that they need permission from Director of LKEMP. Some people go directly to the TANESCO office at Kihansi but they are always referred to LKEMP. Subsequently, the RAMPO has to seek permission from the LKEMP office in Dar es Salaam.

3.4.1 Safety protocol

Anyone who wishes to visit the Kihansi Gorge must walk in, and those who are involved in maintenance, monitoring and/or research must do this on a regular basis. No physical entry barrier has been erected but usually visitors are accompanied by Gorge attendants.

Security checks in the Gorge to prevent poaching, logging and fuel wood collection are undertaken through daily patrols by the attendance crew. Records of any infringements are kept in the waterproof logbook. There has been no reported incidence of logging or fuel wood collection since June 2004.

The Safety Protocol for Disease Prevention in Appendix 7 of the EMP has been implemented and is enforced. This includes footwear and equipment sterilization, waste water treatment, handling of the Kihansi Spray Toad (KST) and replacing of sprinkler systems parts. Simple facilities have been erected for shoe/foot-bath with bleach at the entry and exits points above and below the

Gorge, as well as prior to entry into the spray zones. We were told the bleach is changed twice per month.

The audit team recommends the following issues for follow-up and/or rectification:

- → It appears that the enforcement of the bleach foot bathing procedures, as observed during the on-site audit, can be improved.
- → Despite the patrols, we were told the problem of theft of equipment persists by people entering the Gorge. Preventive measures should therefore be taken.

3.5 Ex-situ Captive Breeding Programme

We were informed that the ex-situ captive breeding programme of the Kihansi Spray Toad started as planned in December 2000. The results of the captive breeding programme as reported in the reports received from the U.S. Zoos between 2002 and 2005 have been summarized in a table in Appendix 7

The responsible institutions and their roles in the captive breeding management programme are detailed in the Breeding Loan Agreement between the US-Based Wildlife Conservation Society and the Government of Tanzania (LKEMP, 2004). It appears that the operation of the programme is complex: A captive breeding basket fund was set up with elaborate financial and accounting procedures. A review of the Breeding Loan Agreement brings out the following issues:

- Data capture: Relevant data gathered through scientific studies were supposed to go into Tanzania's database for use by Tanzanian Specialists. We were informed that all information received from the captive breeding institutions and relevant ecological information gathered in the past ten years in Kihansi Gorge will be entered in the NEMC/LKEMP ecological monitoring database, which is currently being established. This database and a corresponding website, which is to be maintained by NEMC, will be available for use by both national and international individuals. The expected date of finalisation is December 2006.
- Reporting: The Wildlife Conservation Society (WCS) is required to report to Tanzania twice a year on the current propagation, health status of the specimen/progeny and disbursement of funds remitted by Tanzania. We were informed that reports are being submitted as planned.
- Domestic captive breeding programme: For the 2004 financial year it was planned to engage a consultant to undertake a feasibility assessment for KST ex-situ conservation in Tanzania and to develop a strategy and a programme for reintroduction of KST in Tanzania We were informed that capacity building and a feasibility study for a domestic captive breeding programme are work in progress. Two trips (2003; 2004) have been made by Tanzanian scientists and government officials to visit the American captive breeding zoos with a view to getting practical experience and understanding of captive breeding husbandry. A consultancy to undertake a feasibility

study of a domestic captive breeding programme of the KST is planned for early 2006.

→ While theoretically it would be highly desirable to conduct the Captive Breeding programme in Tanzania, given the immense costs and the technological limitations, it would not seem advisable to maintain the only captive population in Tanzania. We hence recommend that a risk assessment of various combinations of captive breeding efforts be made.

- Timeframe: The EMP outlines that Tanzania remits funds to WCS "… until the species can be returned to Tanzania…." However it is not specified when this will be. The EMP mentions that the captive breeding programme is to be continued permanently (p. 68). IREM studies indicated that it would be unlikely that there would be suitable translocation sites and that there is a real risk associated with translocation. If translocation is not an option, re-introduction in Tanzania can only be considered when the habitat at the Kihansi Gorge returns to a state where the threats to the survival of the KST, including the Chytrid Fungus, have been removed. A decision is outstanding with regard to the continuation of the captive breeding husbandry programme in the U.S.A. keeping in mind the high resource demands in terms of money and technology. The annual cost is over US$ 200,000 out of which LKEMP is transferring US$ 75,000 annually to the Zoos, while the Zoos cover the balance. The above mentioned feasibility study is meant to established if captive breeding will be feasible and more economic in country.
- The EMP requires the Captive Breeding Programme to be reviewed by NEMC on the basis of annual report (p.69). The Breeding Loan Agreement is currently under review to take on board new developments (e.g. reduction of captive stock, development of a live cell line of KST) as well as to appropriately revise the old articles of the agreement.
- The staff from the captive breeding programmes only visited the site after the toads had been hit by the decline from the Chytrids, so the purpose of their visit, to see the "natural" conditions so these could be mimicked in captivity, was not met.
- The Captive Breeding Programme is quite unique. It is the first instance of an African species of toad on Appendix I of Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) being brought into a captive breeding programme. We note that it is difficult to find information about the captive breeding programme from LKEMP. It is not on the website. In general, we observe that the website has few links that lead to data and information.
  - → We hence recommend that scientific information be shared on a wide basis. For example by having a regular public update on a website.

IREM specifically mentions that there is a need to incorporate knowledge from the captive breeding into the studies in the Gorge. However, we could not ascertain the flow of information from the captive breeding programme to in situ conservation and management. The RAMPO on-site handles all the field programme activities and is presently not involved in the captive breeding programme nor did she have any information at hand.

3.6 Kihansi Scholarships

IREM suggested further studies on the biology of the Kihansi Spray Toad, insects and vegetation. Supporting doctoral students to work on different aspects of the ecology of the Kihansi Gorge and spray wetlands was considered an effective means of increasing levels of knowledge and understanding about the Kihansi Gorge and spray wetland ecosystems.

The EMP recommends that scholarships for up to four MSc. and Phd. programmes and funds for competitive research be made available through LKEMP. It appears that the implementation of this component deviated from what was foreseen in the EMP. Table 7 presents an overview on the studies that were planned in the EMP and their status to date, while Appendix 7 provides a full overview of all training activities sponsored and other support provided undertaken under the Kihansi Scholarship component.

Table 7 Studies Conducted under the Kihansi Scholarship Programme

Planned Study (EMP p. 71)	**Status**
1. Maximising habitat, spraying 'toad rock' etc.	This is included in the consultancy on sprinkler back up design and installation
2. General diurnal behaviour, predation, reproduction	Conducted in the Zoos in the U.S. Captive Breeding Consortium
3. Longevity of the toad	Is being conducted under the captive husbandry programme
4. Pathogens of KST, Chytrids fungi in the Gorge	Conducted and finalized by a Chytrid Fungus Expert from South Africa.
5. Food preferences and preferences of the indicator insect species, O*rtheziola* and A*frosteles*	Conducted by P. Hawkes and team but so far only draft report.

The list of training activities actually provided by LKEMP far exceeds what was planned in the EMP. In summary, two PhD and ten MSCs Scholarships were provided, mostly for studies abroad, to students from the University of Dar es Salaam and Tanzanian Government Agencies. The majority of these degree programmes are presently still on going.

In addition 46 short-term skills training courses, and support to attend workshops and professional seminars were sponsored by LKEMP (see Appendix 7). Two lecturers were recruited, one for Conservation Biology and one in Water Resources Management, for the University of Dar es Salaam. Additional support provided included the donation of laptops and other IT equipment as well as motorvehicles and motorcycles. The drafting of the Environmental Management Act (EMA) of 2004 with respective regulations and guidelines was also financed under this LKEMP component.

According to the EMP, further funds were supposed to be made available for competitive research grants and students invited to submit proposals. We were informed, that a Competitive Research Grant Panel was established by NEMC and the LKEMP for the purpose of advertising and selecting Expressions of Interest from among national and international scientists.

According to the EMP, the funding for the Kihansi Scholarship Programme should have been provided by TANESCO after 1. January 2005. However, we were informed, this has not yet happened. A decision was made by both the Government of Tanzania and the World Bank that the LKEMP funds should be used for shouldering TANESCO cost until the end of the project.

In summary, the support provided under the Kihansi Scholarship component of LKEMP exceeded by far what was planned under the EMP. This is both with regard to the quantity of scholarships issued but also with regard to the type of support. The procurement of IT and other equipment was not originally fore-seen, neither were professional short courses and workshop attendance, nor funding of the drafting of the EMA. How the results of this capacity building exercise will be captured to feed into the knowledge about the Kihansi Ecosys-tem and Biodiversity and Water Resources Management issues in Tanzania in general remains to be seen.

In addition it is noted that the Kihansi Scholarships Programme only focused at high level institutions in Dar es Salaam. However there is considerable scope for engaging primary and secondary schools in the LKHP project area.

4 Vegetation

The mitigation and monitoring measures recommended in the EMP form the basis for the audit criteria included in the vegetation checklist (see under Appendix 4). Vegetation impacts highlighted in the EMP are associated with the plant communities in Kihansi Gorge, Udagaji Gorge, along Kihansi River upstream of the dam site, down stream of the tailrace area and in the adjacent woodland in the LKHP area. These areas have hence formed the scope of the vegetation audit. Some findings regarding vegetation monitoring activities were already presented in the overview table on habitat monitoring in Section 3.3.2 above.

4.1 Size of Spray Area and Vegetation Changes

The most significant mitigation measure is the maintenance of a by-pass flow of 1.5 - 2.0m^3/s in the Kihansi Gorge. This flow was predicted in the IREM report to be sufficient to maintain the vegetation communities with little loss of biodiversity. As will be explained in Chapter 5, RBWO and LKEMP data suggest that this minimum bypass flow has so far not been maintained by TANESCO.

Obviously, the by-pass flow in combination with the sprinklers and the fountain jets is only a viable mitigation measure provided that the sprinkler and fountain jets are working properly. This would need to be ensured at all times. However, during our site verification we found that there is no gauge to monitor the sprinkler flow. Pressure is used as an indirect measure for estimating flow.

The amount of vegetation cover in the original spray zone has been divided into a control area and an area to be maintained under the artificial sprinkler system. The LKEMP study selected an area of 400m2 in the center of the wetland (upper spray) from which six (10x10m) random sample plots were measured. The IREM studies extended this area by 100m^2. Of the plots, three are permanently sprinkled, three are control plots in the wetland but not under the sprinklers and two are also outside the sprinklers on the wetland fringes (Gibbs, 2004: 24).

Onsite verification during this audit showed that the vegetation in the control plots, which is largely grassland, is reduced. This is due to the invasion of fringe species specifically *Aframomum* sp, *Costus afer*, which are opportunistically colonising the area following dry spells. These plots rely on the remaining natural moisture available mainly during the wet season.

4.2 Vegetation Monitoring

Despite the recommendation to conduct annual vegetation monitoring surveys (Gibbs, 2004 and EMP) the most recent survey was conducted in 2002 (Taplin and Ndangalasi, 2002). Since the hand over of the project from NORPLAN to NEMC no vegetation monitoring has been conducted.

As described in Chapter 3 above, vegetation monitoring is supposed to be included in the routine habitat monitoring activities. These monitoring activities include the spray zone vegetation, forest woody vegetation and indicator species, in particular Epiphylls. We found that there are gaps in the implementation of these monitoring activities.

We were informed that the next vegetation monitoring exercise will be carried out in early October 2005 by a team of Norconsult experts. For reasons of consistency in the monitoring protocol, the same time period as for the previous vegetation study was chosen.

Due to the lack of vegetation surveys it is not possible to conclude how the current flow has impacted on vegetation changes. The physical spot checks of the audit team revealed that on both upper and lower spray zone the vegetation is doing well. In both areas *Selaginella krausania* is regenerating, which is an indication of sufficient spray in the area for this indicator species to regenerate.

4.2.1 Monitoring of Spray Vegetation

There has been no sampling of the eight vegetation plots in the spray zone since Taplin and Ndangalasi (2002). The RAMPO, who is responsible for monitoring the vegetation plots is not a qualified botanist. We were told that recording presents difficulties in the absence of a botanist, as the monitoring has to rely on the infrequent visits of experts for guidance. The control plot established by the RAMPO and her team in the lower spray wetland receives maximum spray and may not be scientifically well chosen.

4.2.2 Monitoring of Forest Vegetation

According to the EMP forest woody vegetation characteristics are to be monitored annually in 28 sample plots in Kihansi and Udagaji Gorges. Similar to other vegetation zones, the annual monitoring of woody sample plots has not been undertaken since 2002 but is planned for October 2005.

We found that the plots in Kihansi Gorge have been demarcated and given numbers. The trees are numbered as well. However the plot markers are fading and need re-establishment. A few fallen markers were collected by the audit team and placed back on the trees.

The audit team found no obvious change in the *Filicium* forest vegetation. Similarly the humidity data observed (>100) were high enough to sustain this vegetation. No change in size of the area covered by this vegetation type was observed.

During the on-site audit we observed a number of dead trees in one plot close to the camp-site. The reasons for this could not be established.

4.2.3 Monitoring of Indicator Species

The habitat monitoring within the Gorge Ecosystem includes checking on indicators species, to allow conclusions on vegetation changes due to a change in moisture levels.

The audit team did a random check to verify the presence of these species. However more systematic studies would need to be required to make conclusions presence and distribution of species.

- *Kupea jonii*, *Kihansi lovettii*, and *Stenandrium grandiflorum* were not recorded during the on site audit. All these species require high moisture levels, thus it was difficult to find them given the season during which the audit was conducted. During the most recent visit by Ndangalasi (May 2005), it was reported that the indicator species were present (pers. comm..with the audit team).

- *Epiphylls* were sighted on leaves along the river but not in the forest. This implies that the forest is relatively dry. Gibbs (2004) recommends monitoring of the epiphylls as an indicator of changes of the microclimate. Monitoring of Epiphylls is included in the forthcoming 2005 vegetation study, however the consultant requested for it to be taken out, as there is no base line study on epiphylls and no protocol has been established (H. Ndangalasi, pers. comm.)

4.3 Related Studies

We understand that no party has been assigned responsible to conduct a mini catchment study, neither in the Gorge nor in inundated areas, as planned in the EMP. It was also not included in the Landscape Wide Conservation Plan for the Upstream Kihansi Catchment (LWCP). Similarly no additional studies have been conducted to assess the improved use of fountain jets on vegetation and their alternatives.

There has been no recent land cover monitoring study to check changes in vegetation. However, the RAMPO has used photographs taken regularly to monitor the changes of vegetation over time. The RAMPO noted an invasion of plant species characteristic to dry area into the spray wetlands. This is undocumented and requires further confirmation.

Based on the above findings, the following recommendations are made:

→ A further study is required to monitor if there are changes in vegetation characteristics with the current flow regime.

→ The RAMPO should be trained further particularly on aspect of plant identification.

→ The establishment of a baseline and scientific protocol on epiphylls monitoring is required.

5 Kihansi River Hydrology

The hydrology audit included the verification of the implementation progress of the mitigation and monitoring measures listed in the up-dated EMP (p.61f & 78f).

5.1 Final Water Right

The Final Water Right (No. RBWO 16) was granted to TANESCO on 30 June 2004 based on the Water Act of 1974 Section 15 by the Central Water Board of the MWLD. It allows storage of 1.6 million cubic metres and abstraction of 2,151,360,000 litres of water per day for 180 Megawatt hydropower generation, while leaving between 1.5 and 2.0 cubic meter per second for environmental flow. Reservoir sediment flushing is only allowed with approval of RBWO and NEMC and has so far not been practised.

Based on the Water Right, the following daily records are to be kept:

- Water level
- Storage of reservoir
- Turbine discharge
- By-pass flow
- Spills

We were told that this data is being measured by TANESCO at the site and daily reports are sent to the Director of Hydropower Generation in Dar es Salaam. Reports to RBWO are sent weekly containing the water discharge values. Receipt of these reports was confirmed by the RBWO.

There is a requirement in the EMP that TANESCO procedures and records have to be modified to conform to those of RBWO. We were told that TANESCO is not aware of this requirement and it is unclear to what extent a modification is required.

→ This issue needs to be clarified or if no longer applicable to be deleted from the EMP.

5.2 By-pass flow

TANESCO is monitoring the bypass flow as required by the Water Right and prepares hourly, daily and weekly reports, which are sent to TANESCO Headquarters and to RBWO. Hydrological data generated in the powerhouse control panel shows that a bypass flow of between 1.5 and 1.9 m^3/s has always been released depending on the water level (meter a.m.s.l) in the dam.

Measurements carried out by RBWO and an alternative consultant study commissioned by LKEMP indicated that 1.30 – 1.40 m^3/s is being released depending on the reservoir level.

We confirmed that TANESCO has commissioned NORPLAN, who is responsible for the initial design, to resolve this discrepancy. The contract for "*remedial works to augment the minimum bypass flow releases at the Kihansi pond*" was signed 13 June 2005 and is currently running for a 19 weeks period. The scope of work includes the design of a facility capable of releasing a minimum of 1.5 m^3/sec at all times by lowering the discharge point of the existing bypass pipe by a few metres and the recalibration of the by-pass display metre at the power station control panel.

Site level work had not yet started at the time of the on-site audit. We were informed that pipes had just been procured and are about to be cleared at customs.

The audit team recommends the following issues for follow-up and/or rectification:

→ TANESCO has not commissioned any study for alternative sources of water to substitute for the bypass flow as stipulated in the EMP. We were informed that this activity had not been given a budget allocation and was given low priority even by the World Bank representatives when the EMP was discussed. The reason given is that using an alternative source would lead to a 'replacement effect' since the water for Kihansi would need to be taken away from a different source. If this activity is not considered relevant anymore, the EMP should be revised accordingly.

→ There is no evidence of unusual events, such as uncommon high or low flows, being reported immediately to RBWO and NEMC via UHV radio as required in the EMP. However a discharge report is sent to RBWO on weekly basis.

→ RBWO should explore the possibilities of using a rectangular open channel downstream of the dam to periodically verify the amount of bypass flow. This could be established as a routine procedure to provide an alternative to the measurements from the TANESCO powerhouse.

→ RBWO should download data from the loggers on monthly basis for effective monitoring water flows in the Kihansi river.

→ RBWO need to improve reading and collection of data from the river gauge station by providing transport to the responsible staff.

- → Staff gauges installed at river stations need to be used to calibrate the data loggers.
- → The gauging station (1KB28) at the Chita-Mlimba bridge should be rehabilitated and put to work. In the comments received on the draft Audit Report, RBWO disclosed that this station is now functional.
- → The requirement in the EMP that TANESCO and RBWO should exchange hydrological and hydraulic data on the Kihansi river on real time basis needs clarification. Both institutions commented to the Auditors that they are not clear on how to comply with this requirement.

5.3 RBWO – Hydrological Monitoring

RBWO is the institution responsible for the monitoring of the Water Right. There is evidence, through reports and interviews, that this is being done. RBWO has installed data loggers and staff gauges to monitor water flows and levels in the Kihansi River. Water levels are read twice daily.

The EMP requires monthly downloading of the loggers. The local readers reported that RBWO data loggers by RBWO staff are down loaded on an irregular basis, i.e. sometimes after one month, sometimes three to four months or more. Evidence during the on-site audit confirms that data downloaded during the audit had not been read for the last two months. The NEMC "Oversight Monitoring Report of LKEMP" dated December 2004 states that regular monitoring of water flow is hampered by lack of funds by the RBWO.

Five RBWO river gauging stations were physically inspected as part of the on site audit. These were:
1. 1KB28 – Kihansi river at Lugoda, downstream
2. near TANESCO quarry, downstream (no label)
3. Under bridge, near dam, downstream (no label)
4. 250 m downstream of dam (no label)
5. NC1- Kihansi River at Kilatu – upstream

The stations without label could not be named in accordance with RBWO reporting by the local water gauge reader who accompanied the audit team member.

A summary of the audit team's assessment of the RBWO monitoring system at Kihansi is presented in Table 8 below.

Table 8 RBWO Hydrological Monitoring at Kihansi

Monitoring tool	**Findings**
Gauging stations no. 2 to 5. above	• Working properly and readings are taken twice per day.
Gauging station (1KB28) at the Chita-Mlimba bridge (no. 1)	• Lowest river gauge missing at the time of the site verification. As reported by RBWO on 17.September 2005 a staff member visited the station and installed the gauge.

Data loggers	• 3 data loggers have been fixed and are reportedly working • Loggers use batteries and sometimes when out of charge, there is no replacement and no record is taken.
Piezometers (PZ)	• PZ at Uhafiwa Bridge is not working
Automatic level recorder	• Is not working
Rain gauge	• Is not working
Institutional	• RBWO Staff from Iringa office does visit the site on irregular basis • Data are supposed to be collected monthly but according to field staff this is not the case

5.3.1 Responsibility and Training

RBWO assigned a principal technician (hydrologist) responsible for monitoring at Kihansi. We were told that the monitoring is taking place once per month and if sufficient funding for travel is available even every two weeks. It appears from our verification of evidence that the reporting of the technician back to RBWO is not regular, as only three reports were found.

RBWO staff at site has been trained on reading the instruments, however not as outlined in the EMP on:

- Reporting procedures (when to report emergencies, reporting formats etc.);
- Use of radio communication for reporting; and
- Procedure for responding to breaches in Water Right agreement.

5.3.2 Data Collection

The EMP requires RBWO to download data loggers to a card on a regular basis (once per month). Based on our evidence, data is downloaded irregularly. Data was found at the RBWO office from June and July 2005, but was missing for the period 27 September 2003 to 18 July 2004 as well as from mid August 2005. As reported by RBWO this was due to malfunctioning of the data logger.

It was reported to the audit team by RBWO that the staff gauges are used as a control to calibrate the data loggers. However, the hydrologist on the audit team could not verify this on-site.

Based on the EMP, monitoring of diversions for the Kihansi domestic water supply and spray wetlands irrigation is to be done according to RBWO procedures. RBWO specified towards the Auditors that what is meant by ‘standard procedures’ is that the abstraction needs to be based on a valid Water Right. However, this Water Right has not yet been established, which deprives RBWO of a basis for monitoring.

5.3.3 Reporting

A quarterly report is prepared for the Rufiji Basin Water Board (RBWB) and Ministry of Water and Livestock Development (MWLD) providing flow measurement data for the various gauging stations. No separate annual report summarising and bringing together all data recorded during the previous year is prepared. The absence of an annual report may hint at a lack of analysis of annual changes. RBWO reports that analysis is taking place despite the lack of a formal annual report, however this could not be verified by the auditors.

The EMP requires that regular reports are being evaluated by the RBWB and a brief analysis is submitted to its stakeholders.

As reported by RBWO meetings are held on a quarterly basis with RBWB. The Permanent Secretary of the MWLD also attends these meetings. At this meeting they submit the report and discuss it. On basis of the report RBWO are advised by RBWB and at the next meeting they follow-up on the implementation of the advice. Evidence in form of minutes was provided for a first meeting held in December 2004 and the latest in August 2005. No further evidence was provided to support if the meetings are held as required.

5.3.4 Financial Viability

According to the EMP, the RBWO monitoring is supposed to be fully financed by TANESCO and paid via the MWLD as part of the Water Right. We were told that Water User fees are being collected from TANESCO and that RBWO receives no funding directly from TANESCO. TANESCO pays Tshs 165 million each year to the MWLD in Water User Fees of which RBWO receives between 10-40 million Tsh. This is not considered sufficient for monitoring. In addition there is a budget allocation to RBWO of Tshs 10 million from LKEMP each quarter. Although the amount was received for the first two quarters of 2005, the third transfer had not yet been effected at the time of the audit.

The following recommendations are made:

- → RBWO should repair any non-functioning measuring instruments and implement a timely routine maintenance practice. The reading of gauges needs to be undertaken regularly.
- → Training of RBWO staff at site needs to be provided as foreseen in the EMP.
- → The monitoring of diversions for the Kihansi domestic water supply and spray wetlands by RBWO needs to be done in accordance with specifications outlined in a valid Water Right. This Water Right needs to be acquired in order to establish the basis for monitoring.
- → The financial viability of RBWO monitoring needs to be reviewed.

5.4 TANESCO – Monitoring at the Dam

The EMP refers to monitoring of siltation and sedimentation rate in the dam to be undertaken by TANESCO under the sections of mitigation and monitoring at the LKHP works site (p.72f & 88 f respectively).

As required in the EMP, Piezometers have been integrated into the hydrological data collection and TANESCO staff take readings one per week. The assessment of the TANESCO Dam Monitoring Tools by the audit team is summarized in Table 9 below.

Table 9 Dam Monitoring Tools

Monitoring Tool	Assessment
Piezometers	• Measurements are taken once per week • Around the dam PZ 401,402,403,407 and 305 are working; whereas PZ 404 and PZ 306 are not working • Along the headrace tunnel HT 31, HT 32 and HT 33 are working
Stream Discharge V Notch	• No. 1, No. 3, No. 4 and No. 5 are working; No. 2 is not working
Seepage Chambers	• No. 1, No. 2 and No. 5 are working • No. 3 is not there (was never constructed) • No. 4 is dry, i.e. not working
Drain holes measured	• No. 1 at 1st abutment • No. 2 at 2nd abutment

The audit team recommends the following issues for follow-up and/or rectification:

→ A standard procedure for monitoring seismic events and structural stability of the dam should be introduced, as required in the EMP. Purchase of equipment for monitoring and staff training will be required.

→ Standard procedures for monitoring sedimentation rate in the dam and release of sediments from dam during flushing operations should be developed.

5.5 TANESCO – Hydrological Modelling

The hydraulic sub-component of the Catchment Management Plan (CMP) formulated by NORPLAN included hydrometric data collection and the development of a hydrologic model for the Kihansi Catchment. The objective of the model is to describe, quantify and facilitate monitoring of the impacts of land use changes on sediment load and water balance in the catchment. While TANESCO was responsible for the data collection, NORPLAN was responsible for model development. After the end of NORPLAN's contract, LKEMP continued to support TANESCO in the continuation of this activity.

As part of the on-site audit we were only able to visit the gauges listed in Section 5.3 above.[2] A full on–site inspection of the hydrological stations was not possible. Our observations in this Section are based on a desk review of the report of TANESCO/LKEMP "*Support for data collection and hydrological modelling"* (date up to May 2004).

The report was provided to the team by TANESCO in Dar es Salaam as an example illustrating the Hydrological Model. The most recent report was not available during our visit. While some of our comments below might be outdated, others relate more to issues of principal and will hence still be of relevance.

- → We note inconsistencies in the reporting on the total number of gauging stations. While some pages mention 11 stations, others mention 12. In some paragraphs there are 2 downstream gauges, in others 3. These inconsistencies should be corrected.
- → The responsibilities/ownership of the various gauging stations is unclear. Sometimes Maji is mentioned, at times RBWO, or TANESCO. A more consistent presentation based on the actual ownership would be desirable.
- → On page 3 it is mentioned that the 3 Automatic Weather Stations are not working. While this might have been rectified by now, we note the high rehabilitation cost involved (Euro 2,269.00). As a general issue, it might be recommendable to verify to what extent foreign technology can be replaced by simple, locally available technology so that parts and spare parts for various equipment under LKHP can be obtained at more reasonable prices. The current set up is not financially sustainable and therefore needs to be revised.
- → Page 3 mentions the outstanding recruitment of a resident technicians. Their recruitment should be given priority.
- → 12 manned rainfall stations are mentioned. TANESCO at site is not aware of the rainfall stations. They only download data from data loggers. We were unable to verify who the 'manned' person is. It appears that there is a gap in local staffing and responsibility for reading, maintenance and regular reporting on Kihansi River Hydrology.
- → Running the system out of Dar es Salaam will be less efficient and more costly in the long-run. Hence, a change in management structures, favouring those closer to the operations may yield efficiency gains and operational improvements.

The EMP requires that TANESCO and RBWO exchange hydrological and hydraulic data on the Kihansi River on real time basis. The auditors received inconsistent information from the various parties interviewed regarding the exchange of data between the two institutions. While during the on-site audit it was confirmed that real time data exchange is presently not achieved, in the comments received to the draft audit report, the information was transmitted

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[2] Due to an accident of the LKEMP driver, the planned verification of catchment gauges had to be cancelled.

that TANESCO and RBWO maintain the same database. At the same time RBWO reported that information is exchanged but not on a regular basis. This audit can therefore not make a conclusive recommendation regarding the extent and speed of data exchange between the two institutions.

Both institutions raised towards the auditors that they were unclear of what is meant by 'real time' exchange. It is therefore recommended that the requirement in the EMP that TANESCO and RBWO should exchange data on real time basis be clarified or removed (if not applicable) in a revised version of the EMP, should it be prepared.

6 Erosion, Fire Control and Solid Waste

Other issues at the LKHP Works Site listed in the EMP include re-vegetation and other erosion control measures, control of wildfires as well as waste management.

6.1 Control of Erosion and Fires

Re-vegetation in previously excavated areas is practiced. As part of the re-vegetation efforts, *Vertiver* grass was planted and terraces were constructed. Other erosion control measures include gabion boxes, stone pitching on road sides for storm water open channels. These measures are being maintained by TANESCO through casual labourers.

With regard to erosion of the riverbed, an assessment of the river channel downstream of the tailrace during the on-site audit indicates absence of erosion problems.

The uncovering of scrap metal from the construction site by a local contractor at the LKHP works site, observed during the on-site audit, is counterproductive to the on-going re-vegetation activities and presents a potential health hazard.

Furthermore of relevance to the environmental audit are frequent outbreaks of fires in the LKHP project area. During the on-site audit a fire broke out that had been started on one of the fields cultivated by TANESCO staff and the villagers had put it out. It was reported by TANESCO that despite disciplinary action the prevention of bush fires is a problematic issue. The villagers, through their environment committees, are perceived to have better means of fire prevention and control than TANESCO. On 17 and 18 October 2005 considerable fire damage was caused in the woodlands directly adjacent to the Gorge (D. Mtui, pers. comm..). Although the auditors were informed that a number of measures for fire prevention and control are under implementation through the EMP, including provision of fire breaks and sensitisation and awareness raising campaigns, the frequent fires outbreaks show that these measures are not sufficient and more effective prevention and control measures therefore need to be established.

The audit team recommends the following issues for follow-up:

→ Although erosion control and re-vegetation of excavated land have been practised there are no standard procedures for monitoring and it is dealt with on an ad-hoc basis. A more systematic system would allow further improvements.

→ Active prevention and control of fires by TANESCO is needed on an urgent basis.

6.2 Solid Waste Disposal at LKHP Works Site

The EMP under mitigation measures at the LKHP Works Site mentions solid waste management programmes, among others, without providing further specifications. During the on-site audit we therefore assessed the waste management practices at the TANESCO camp and in the Gorge.

Overall, we note that there are no standard procedures for solid waste management neither at the LKHP Works Site, nor in the Gorge.

There is no Head Engineer responsible for environmental mitigation measures at the LKHP work site. There is one TANESCO staff, at Civil Technician level, who has been assigned these responsibilities, however based on the findings of on-site visit this appointment does not seem adequate to address the most pertinent issues as well as more medium and long term environmental mitigation. In particular with regard to waste disposal some commitment and immediate action of senior management is required.

The current disposal practice is to transport the waste to an open dump-site at about 1 km distance from the TANESCO camp, where there is irregular open air burning. More recent waste materials are mixed with solid waste that remained from the construction phase, including used oil filters, batteries, scrap metal, scrap plastic and rubber materials. The current disposal practices present a problem for the following reasons:

- These wastes continue to persist long after disposal;
- The wind is spreading the waste around;
- The dumpsite is not fenced and hence creates a public risk due to chemical or infectious exposures;
- Wastes can breach and contaminate groundwater; and
- The dump site is frequented by animals (scavengers) who feed on the biodegradables, as well as people.

The 2004 Environmental Management Act (EMA) prescribes, under Sections 116 (1) and (2), that industries provide adequate spaces and facilities for managing solid waste generated from such industries. ‘Adequate’ is specified under Section (2) as ‘refuse bays’ or ‘areas are set aside by industries for the collection of solid waste’ that are ‘clean, protected from flies, animals and scavengers’. TANESCO is presently not in compliance with these requirements at LKHP.

Furthermore, Section 110 of the EMA “prohibits the discharge of any hazardous substance, chemical, oil or mixture containing oil in (…) any segment of the environment (…)". A person or organisation doing so, commits an offence and may be ordered by the court apart from the general punishment provided under the Act to a) to pay cost of removal and b) the cost of third parties in form of reparation or compensation.

→ We therefore recommend that TANESCO appoints a resident engineer responsible for solid waste management and that safe procedures for waste disposal are implemented and monitored.

6.3 Solid Waste Disposal in the Gorge

The maintenance of the sprinklers will require the presence of a team of workers over a long time period, essentially indefinitely. It is important to view the problem of human waste disposal from a long rather than a short perspective. We noted batteries thrown into the latrine. When these disintegrate, they are likely to eventually leach into the Gorge system and cause problems.

Visitors need to bring in plastic water bottles, food in tins, paper and plastic wrappings and containers. When asked how these were dealt with, two different answers were given. One individual said that all of the waste was carried outside the Gorge and deposited in a dump (presumably at the TANESCO camp). A different individual responded that the waste was burned (for paper) and other waste was buried in the Gorge.

On this issue, the audit team has the following recommendation:

→ Waste disposal should be treated as a long-term issue and it is reasonable to expect that at least non-burnable, non-biodegradable waste be carried out of the Gorge and properly disposed. Certainly, all plastic waste should be carried out. This policy needs to be made clear to staff and visitors. Tins could be washed, collected, and another porter hired to carry down such a load.

7 Occupational Health and Safety

The Health and Safety Audit included a verification of the compliance of the Kihansi Hydropower plant with TANESCO's Health and Safety Policy of January 2005. In addition a number of health and in particular safety issues emerged during the on-site visit of the Gorge, currently managed by LKEMP. These are also reflected here.

7.1 Compliance with TANESCO Health and Safety Policy

On the basis of the audit, the occupational health and safety procedures at the Kihansi Hydropower Plant are in substantive compliance with the January 1995 TANESCO Health and Safety Policy, with the exceptions stated below. The findings below warrant follow-up and rectification.

- Tenure of Safety Representative (Policy item: 2.1.1). The policy requires that for major field operations a Safety Representative (SR) be appointed for a term not exceeding 12 months. A SR was appointed through official communication from TANESCO Headquarters on 5 November 2002 but there has been no re-appointment since then, leaving the current officer in charge for a period much longer than 12 months.
- Attendance at Safety seminars (2.12). The Policy requires that the company's field staff attends at least 5 seminars per year without specifying which category of staff or scope and duration of seminars. On the basis of the interview with the Kihansi TANESCO SR, we understand that staff does not attend 5 seminars per year. Although the SR reported that he attended various training courses conducted both by TANESCO and external trainers, such as the Red Cross, he had not yet attended any course this year. In 2004 he attended 4 seminars.
- Safety Audit (2.16). The Policy stipulates that as part of safety monitoring an annual Safety Audit is conducted with a maximum period of two months to take corrective action on any defects. We verified through physical evidence that internal audit reports are prepared quarterly and sent to TANESCO Headquarters. However reportedly, there is no follow-up on these audit reports.
- Running Risk Assessment Programme (2.7.2.). Station Safety Representatives are appointed and station accidents are recorded in an Accident Record Book, the presence of which was verified. However, beyond that there is no comprehensive risk assessment 'made to employees regularly',

as the policy requires. The wording of the policy is not clear, but it is assumed that risk assessment of stations is meant and not individual employees.

- Emergency preparedness (2.23). The Policy requires ensuring emergency preparedness (for dam failure, tower failure, generator failure etc.) in the chain of command. This includes that emergency drills are being conducted regularly. It was reported to us that emergency preparedness is not achieved for the following reason:
  - No emergency drills have yet been conducted;
  - The emergency telephone system in the powerhouse not working; in case of an emergency the staff would need to call externally for rescue;
  - The various facilities, office area and residential area are not in walking distance to each other, however no emergency transportation is available and sirens are missing.
  - There are no radios for the security guards. The non-availability of a radio at the dam presents the largest risk. As we were told, the security company was supposed to provide radios but they have not delivered. The SR at Kihansi has no means of enforcement as the company is contracted through TANESCO Headquarters.
  - An emergency evaluation is outstanding.
- First Aid equipment at key locations and in vehicles (2.1.4) The policy requires provision of First Aid equipment at every workplace and in each vehicle. First Aid kits were found in 12 key locations, however, they are not well equipped and not refilled regularly. In some instances the key for the kit was not available. A problem of theft of first aid items among workers was reported. There are no First Aid boxes in vehicles.
- Fire fighting equipment (2.14). The requirement is that fire fighting equipment be available and serviceable at all installations and in motor vehicles. Although fire extinguishers are available in most installations and some (not all) vehicles, the service of fire fighting equipment is overdue. The SR requested fire blankets. Reportedly the request remained without follow up from Headquarters.
- Regular medical check-ups of staff (2.7.3). Although required by the policy, there are no regular health checks of staff.
- Disease and Accident Reporting to Ministry of Labour (2.17). We were informed that reporting of diseases and accidents to the Ministry of Labour is not undertaken.

7.2 Safety Management and Control System

The observations on the overall managerial approach and the Kihansi TANESCO safety control system refer to matters that are not specifically required for compliance with the company safety statute. However, they relate to areas of potential concern that, in the audit team's judgement, need attention or improvement:

→ Follow-up and Enforcement. The managerial procedures for safety concerns pertaining to TANESCO are formal and centralized and have to go from Kihansi to the Headquarters in Dar es Salaam. While this is often the case in site-level operations it can, in the event of slow response from the central decision making organ, make an otherwise well established safety system at site function only sub-optimally. Although all of the exceptions from the policy have been noted by the Safety Representatives and are reflected in Safety Audits and various communication between the Kihansi plant and Headquarters, lack of authority for local decision making and delayed feed-back from Headquarters have led to non-compliance. The system therefore needs to significantly revised to provide for more effective and direct response to the various security concerns.

→ Institutional Responsibilities. The TANESCO 1995 Health and Safety Policy is inconsistent with regard to the institutional responsibilities for health and safety issues. While being a joint policy for health and safety issues, it requires only the appointment of a SR. Although Health and Safety Committees are supposed to be established it remains silent about where the overall responsibility for health issues lies. Our observation during the on-site visit was that this separation of responsibilities is reflected in the field level implementation of the policy. While the SR deals with safety issues only, health issues have been delegated to the clinical officer at the dispensary, who is also a member of the health and safety committee. There is no officially appointed Health Representative. Although, as mentioned above this is not required by the policy, it might be an advantage to have such an appointee to ensure better enforcement of the health related aspects in the policy.

→ Pest control. There are no measures of pest control and rats have invaded the facilities at various places, most importantly in the switchyard. This presents a hazard and should be addressed as a priority.

7.3 Health & Safety Issues in the Gorge

The steps taken under the IREM project to improve accessibility and safety for visitors to the Kihansi Gorge are commendable, as are the continued efforts at maintaining the walkways, bridges and ladders (see section 3.2 above.).

However, it appears that there are some improvements to be made in the interests of safety. These are described below.

7.3.1 Suspension bridges

→ The suspension bridge at the bottom of the Gorge needs to be strengthened and made more stable, possibly by the addition of a third longitudinal support cable. Currently there are only two. The spacing between the horizontal planks also needs to be re-examined. It is possible for someone's foot to slip between the gap between the planks if this is too large. The presence of two handrails on the lower bridge is a positive feature.

→ However, the suspension bridge in the Upper Spray zone needs some attention. Two handrails are needed, and in the areas receiving spray, especially on the west side, the boards were extremely slippery. The addition of chicken wire mesh nailed to these boards would provide much needed traction for feet. On the western portion of the Gorge, the area immediately adjacent to the bridge is a slippery, wet rock area. There needs to be a safety railing here to prevent visitors from slipping on the rock and falling into the Gorge.

7.3.2 Wooden Steps

→ The steps are very useful and well constructed, but the handrails need to be sanded to avoid that splinters injure peoples' hands. This also applies to the ladders going up the steep rock faces to the water intakes and the top of the falls.

→ We noted that boards of the steps had recently been replaced, but that the older unusable boards had simply been thrown aside. Such materials should be removed from the gorge.

7.3.3 Latrines at Visitors Camp and Gorge Technician Camps

→ The Latrines need to have a basic roof. This does not need to be of metal sheeting, it could be simply plastic sheeting. This will improve the facilities for users but also to keep water out of the latrine.

→ It is important that each "squatting plate" be stable. The easiest way to do this may be to use a preformed squatting plate, or to cast one at the site.

→ The hole of the pit latrine needs to be kept covered in the interests of cleanliness and disease control. A simple lid would be sufficient. It would be useful and low cost to obtain information on standards used to build latrines in other wilderness or ecologically sensitive areas and see that those at Kihansi conform to these.

7.3.4 First Aid, Health and Safety Training

→ A first aid kit needs to be kept in the Gorge, as does a stretcher, thus facilitating evacuation. Staff needs to be given basic training in first aid. In addition to falls, sprains, broken limbs, accidents involving sharp edges (knives, pangas) as well as fire (cooking, hot liquid spills) can be expected. We were not provided with information as to what potentially hazardous chemicals might be used as part of the work routine (examples are battery acid, caustic substances, Jik), however training in how to deal with harm from these needs to be addressed.

→ We were told that the RAMPO has been requesting a first aid kit since 2004 from LKEMP but without response. We recommend this request be met.

- There are no medical check ups for Gorge technicians and no training on safety and emergency measures is provided. Regular check-ups and capacity building seems warranted
- We understand that there has been no type of accident response or rescue training. There are a number of potential situations, e.g. a fall from a ladder, or into the river, snake-bite, scorpion sting etc., for which such training would be useful. We consider it important for LKEMP to think proactively and anticipate rather than respond to potential accidents.
- A further issue to take into consideration is the risk of infection from Rickettsia (Tick Fever), a general term used to describe the symptoms caused by a certain group of bacteria that are carried by ticks. Apparently it is not possible to confirm its presence using existing facilities in Tanzania, and their blood samples had to be sent to a specialised research facility in South Africa. Gorge technicians and the RAMPO indicated that they frequently were exposed to numerous tick bites. We recommend that as a minimum, the RAMPO and Gorge technicians be made aware of the symptoms of Rickettsia and medical personnel associated with the project also receive this information, and on treatment. The most effective and sure way to deal with the issue would be to regularly test the blood of those who work in the Gorge for Rickettsia causing organisms and treat them if these are found to be present (a specific group of antibiotics can do this if used properly). Since the time of LKEMP, it is possible that facilities in Tanzania for the detection of Rickettsia have become available; it is worth investigating this option. This issue could also be important for TANESCO staff.
- The Gorge Technicians raised contractual concerns towards the audit team. Employee terms and conditions need to be adequate to recruit, retain and motivate staff. It is important that they have medical insurance and work under adequate health and safety conditions.

8 Institutional Aspects

The institutional arrangements of the EMP are complex. The four areas, Catchment, River, Gorge, and LKHP Works Site require the involvement of a range of stakeholders. Monitoring and reporting responsibilities for the various actors are defined in the EMP. Table 10 provides our compliance check against the EMP.

8.1 Monitoring, Reporting and Training

Table 10 shows that while some crucial monitoring and reporting responsibilities are fulfilled as planned, overall the current monitoring and reporting system is not fully in compliance with the arrangements defined in the EMP. Two particular areas warrant action from the authorities:

- → First of all, the lack of compliance may be an indicator that some of the reporting requirements may be too cumbersome or not rational. In those cases, the EMP should be adjusted to simplify the reporting system. The EMP (p. 91) notes that "it is expected that the institutional arrangements will need to be revised".
- → Similarly, the institutional roles have changed from what was foreseen in the EMP. One such example is that the EMP mentions that the responsible institution to subcontract habitat monitoring activities, including vegetation monitoring is TAWIRI (p.84). In practice LKEMP/NEMC has subcontracted all consultants. Such deviations either need to be corrected or the EMP revised.

Some other shortfalls are key deficiencies as they present crucial components of a monitoring system and hence need to be rectified. Without those, the iterative nature of a monitoring system through the cycle of monitoring, auditing, review and revision of the mitigation measures, cannot unfold. These issues are described below.

8.1.1 Annual Monitoring Reports

The EMP states that NEMC is in charge of monitoring the EMP, including the commissioning of environmental audits. NEMC has direct responsibilities to undertake spot checks and prepare monitoring reports with regard to the catchment. The institutional chapter of the EMP specifies that with regard to the

Gorge Ecosystem however, an annual monitoring report is to be prepared by the Wildlife Division and not by NEMC. This system is not followed in practice and may hence need to be reviewed.

Presently, the WD is not preparing an annual monitoring report summarizing all monitoring data collected in the Gorge Ecosystem. The annual report, if provided, would fulfil two important functions in the monitoring system:

- The compilation of the data collected through the various specialized studies throughout the year;
- The review process, allowing for a comparison of current vis-à-vis previous years to assess change.

The lack of an annual monitoring report is an indication that data is not systematically collated on an annual basis, analysed and reviewed to verify whether an adjustment of mitigation measures is required.

As pointed out by the World Bank in the comments received on the draft environmental audit report, the improvement of the implementation of the EMP and achieving the desired results will to a very high extent depend on application of survey, research and other findings to help adjust targets and measurable indicators. In the absence of these the reintroduction of the KST for example will be difficult as there will be no way of measuring the readiness of the ecosystem for reintroduction. Improvement of the system to resemble its original status is an important indicator but this is only possible if ecosystem monitoring and data analysis are regular.

We were told that NEMC is conducting regular oversight monitoring visits twice per year and verified this through three sample reports (August 2003, February 2004, December 2004). A brief review of the sample reports does not show a systematic verification of activities against the EMP. This might be due to the lack of targets in the EMP, which makes systematic monitoring and reporting difficult. We were unable to confirm what happens with the recommendations of the NEMC monitoring visits and where and if follow-up action is taken.

In addition to the evaluation reports, NEMC is (per EMP) supposed to prepare an annual monitoring report for the Kihansi Catchment. No such reports were available during the audit. An annual monitoring report on catchment issues will become even more important once the LCWP is moving into implementation so that its progress and efficiency can be verified. Therefore this is an important part of the EMP that should be adhered to.

Another deficiency is that environmental audits were not carried out bi-annually as foreseen in the EMP. The EMP does not specify if the bi-annual audits are supposed to be internal or external audits. It is the view of the audit team that for external auditing, an annual cycle may be sufficient. In contrast, internal audits, may be required more frequently, as there is a need for regular management feedback and internal control. Internal audits are also relatively straightforward and low cost.

Based on the above the following recommendations are made:

→ In order to remedy the abovementioned shortcomings regarding data analysis and utilisation of the results to review the EMP a number of key steps are required:

- Revise/Amend the EMP to include a clear monitoring plan in the form of a logical framework. This would include clear targets to be achieved, timeframes, quantifiable indicators and clear institutional responsibilities for monitoring and evaluation.
- Establish an annual monitoring cycle with institutional work plans that define the responsibility for data collection for the agreed indicators, and an annual review process.
- During the review process the key parties involved in the EMP implementation submit their annual monitoring reports, which report back against the workplans. The outcome of the review process should be that annual changes of key indicators have been assessed and documented, recommendations for any required adjustments of the mitigation and monitoring measures have been made, agreement on key outputs for the institutional workplans for the forthcoming year has been reached.
- Although for example the RAMPO is currently preparing and submitting an annual monitoring report, it is not based on a strategic logframe and the report remains without feedback from the LKEMP Secretariat.
- Establish and up-date regularly a repository for all data collected through studies and consultancies conducted under the framework of the LKHP. Make data widely available through a website and distribute hard-/soft copies to immediate users, i.e. RAMPO, TANESCO field staff etc. monitoring cycle.

→ Annual monitoring reports of the catchment need to be routinely prepared by NEMC.

→ A regular cycle of annual external and bi-annual internal audits should be implemented.

Table 10 Monitoring and Reporting Responsibilities in the EMP

Management Unit	Institution	Responsibility	Assessment
Kihansi Catchment	NEMC	Key responsibility for mitigation and monitoring	
		• Produce evaluation reports and spot checks	• Being done. Evidence found for 3 reports
		• Evaluate AgES, RBWO, FBD 4 monthly reports	• Not being done.
		• Produce annual monitoring report, copies presented to AgES, MoA, RBWO, MWLD	• No evidence found
	Ages, RBWO, FBD	• Submit regular 4 monthly progress reports to line ministries, copied to NEMC	• Not being done
Kihansi River	RBWO	• Monitoring of flow	• Is being done, though with shortfalls (see Chapter 5) • Financing of monitoring activities not sufficient
		• 4 monthly reports to RBWB and MWLD with flow measurements	• Reports submitted to RBWB. • Flow measurements sometimes incomplete.
	RBWB	• Analyse RBWO reports and send to NEMC and TANESCO	• No evidence found.
	TANESCO	• Send discharge and flow data to RBWO	• Is being done on weekly basis.
Gorge Ecosystem	NEMC	• Overall monitoring responsibility • Bi-annual auditing	• So far only 1 audit (this one).
	TAWIRI/RAMPO	• On-site habitat monitoring • Sub-contract specialised elements	• Is being done • Sub-contracting being done through LKEMP
	TANESCO	• Fully financing of Gorge monitoring based on bilateral agreements with implementing agencies. After regulations of EMA have passed, fundings needs to be transferred into Environmental Management Fund	• Not done.
	TAWIRI Monitoring and Mitigation Team at Gorge	• 4 monthly progress reports provided to Wildlife Division • After each visit of MNRT provide monitoring reports copied to NEMC; providing information on the performance of mitigation measures, prioritising actions	• Reports prepared but provided to LKEMP • No evidence found.
	WD	• Prepare annual monitoring report summarizing all compiled data, copies to each line ministry and NEMC;	• Not being done.
LKHP Works Site	TANESCO, Head Engineer	• Monitoring of activities • Reporting based on internal procedures	• Is being done. • Reporting is done.

8.1.2 RAMPO Annual Workplan and Progress Reports

We verified quarterly reports sent to LKEMP and TAWIRI. There is no institutionally agreed workplan for the RAMPO but she develops one for her own purposes. We were told that there is usually no follow-up on the reports.

While the RAMPO is preparing an annual work plan and provides the required quarterly progress reports, these reports are currently provided to LKEMP and not the WD as outlined in the EMP. This, in our view is however not the most crucial issue. More importantly, the work plan is currently based on the RAMPO's own initiative and not institutionalised. For example, it is not based systematically on the objectives of the mitigation programme and the review of progress. We therefore recommend that

→ Progress reports are reviewed regularly, work plans are formulated subsequently and action is taken in a timely manner.

8.1.3 TANESCO Funding of Mitigation in the Gorge

TANESCO is presently not funding the mitigation and monitoring activities in the Gorge as required per EMP. We were informed, TANESCO is planning to budget for this in the next financial year 2006/07.[3]

→ TANESCO needs to take responsibility for the monitoring and mitigation programme in the Gorge and budget accordingly.

8.1.4 Training Provided

The EMP foresees that various implementing institutions, i.e. RBWO, Health Department, Agricultural Extension Service (AgES), Forestry and Beekeeping Division (FBD) and TAWIRI field staff; undergo training on reporting procedures. Such training was not provided. However, we could also not establish evidence that uniform reporting procedures have been developed.

→ There is hence a need for clarification if such procedures need to be formulated and training to be provided accordingly.

8.2 Coordination

The EMP outlines two areas of coordination, government agencies amongst themselves, and coordination with local stakeholders.

The LKEMP Multisectoral Steering Committee (MSC) and the Multidisciplinary Technical Advisory Committee (MTAC) provide the basis for coordination activities within government.

We note that two of the implementing agencies of the EMP are not included in either the MTAC or the MSC. These are the Ministry of Agriculture Extension Service responsible for land use, encroachment and use of agrochemicals; and the RBWO. Similarly, none of the District Councils participate in the LKEMP

[3] Pers. Comm. With TANESCO on 07.07.05

Coordination bodies. Districts are represented by their respective Regional Administrative Secretary (RAS). Whilst the inclusion of the RAS of Morogoro and the RAS of Iringa Region in the MSC is based on the assumption that information is shared systematically with the relevant District Councils, it seems that this is not always the case. Mufindi District recommended to the audit team that regular meetings should be held with LKEMP and TANESCO to increase information sharing.

All the above institutions are classified as 'local stakeholders' in the EMP. This may explain their exclusion from the MSC and the MTAC. Since these institutions are however mentioned as implementing agencies under various components of the EMP, a problem arises if they do not have sufficient access to information.

With regard to coordination with local stakeholders we note that the EMP includes requirements for public disclosure of environmental monitoring results. Specialised reports will need to be translated into Kiswahili and shared with the public. Whilst we found no evidence to support that this has been done, we note that the EMP remains silent about 'which' data needs to be published and which form of public disclosure/consultation is recommended. This needs to be clarified.

It is against this background that we recommend:

→ A review of the institutional set up of the LKEMP with a view of full inclusion of all relevant stakeholders and more complete and timely sharing of information.

→ Public disclosure of environmental monitoring results and studies undertaken by LKEMP. The public includes not only the national and international research community but also village communities around Kihansi and elsewhere in Tanzania.

8.3 Ultimate Responsibility for Mitigation and Monitoring

Presently, the implementation responsibility for the mitigation measures in the Gorge lies with LKEMP/TAWIRI through the RAMPO. The EMP mentions the "*agency ultimately responsible for mitigation*" without clarifying who this is.[4]

The minutes of the LKEMP Midterm Review Process state that the ultimate responsibility for the Kihansi Gorge environmental management and monitoring system remains with the developer, TANESCO. This responsibility has been confirmed to us in our meeting with TANESCO staff as part of this audit. The question remains to what extent TANESCO is building capacity and financial reserves to prepare for the take over after December 2006, when LKEMP closes.

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[4] in footnote 17 on page 71

In this context the aspect of decommissioning is also relevant, which is dealt with in Section 8.4 below.

It is also important to note that TANESCO has not yet received the Land Title for the project area at Kihansi. Although the process has been initiated in 2001/02 it is still pending with the Ministry of Lands.[5]

Hence, recommendations to be made are that

→ the long-term institutional responsibilities for the Kihansi area need to be clarified and formalised in documents and through the creation of job responsibilities; and

→ the process of granting the land title needs to be finalized.

8.4 Decommissioning

The EMP (p.72 and p 105) under mitigation measures at the LKHP Works Site requires that a decommissioning fund be set up within TANESCO to cover for the cost of the decommissioning of the dam after the project's lifespan. The estimated financial cost for decommissioning is about US$ 35,000 annually over the expected lifetime of the dam of at least 50 years. The cost and negative environmental impacts (in particular reservoir silting) associated with decommissioning are large.

In addition, the Environmental Management Act, 2004 Section 102, sets the legal basis, requiring TANESCO to "*undertake safe decommissioning, site rehabilitation and ecosystem restoration upon the expiry of a project.* "

We were informed that, to date, TANESCO has not set aside any funds for decommissioning. This is due to the misconception that building these financial reserves is not required as long as there is LKEMP/World Bank support to the project.[6]

A question arises also regarding the long term responsibility for the Kihansi Area, even after decommissioning. There might be long-term environmental impacts associated with the hydropower project. It is important for the managers of the Kihansi area, that only TANESCO, but others, study cases from other countries in which dams have been decommissioned and to learn from their experiences, not only for LKHP, but for other hydropower projects.

In conclusion, the team would like to make the following recommendation:

→ TANESCO, involving other stakeholders, is encouraged to plan for and set aside funds for decommissioning, incorporating lesson learned and best-practise from other decommissioning projects. Careful planning needs to include Human Resources planning and development.

[5] Pers. Comm. With TANESCO on 07.07.05

[6] Pers. Comm. with TANESCO on 07.07.05

→ Since TANESCO has no prior experience of decommissioning a hydropower dam, we recommend that several key TANESCO staff receive training in the complexities of this topic. This shall include among others impacts on public health, socio-economic impacts, risk assessment, and biodiversity related impacts.

Part 3 - Socio-Economic Aspects

9 Introduction

This part of the report deals with socio-economic aspects in the villages adjacent to the LKHP area. While the EMP does not include any socio-economic mitigation or monitoring measures for the adjacent communities, it does refer to a Landscape Wide Conservation Plan for the Kihansi Upstream Catchment (LWCP) as an instrument to operationalize such measures. As the LWCP had only just been finalised at the time of this audit, the assessment of the implementation of social mitigation measures is limited to a theoretical verification of the extent to which the various potential social impacts identified in the EMP have been addressed under the LWCP.

In addition, it was agreed with the Client during the pre-audit meeting that a wider assessment of socio-economic aspects would be included in the environmental audit. The focus would be twofold: firstly to verify if the activities of the previous community programmes conducted during the LKHP construction phase have been continued by the Local Authorities; and secondly, to provide a 'quick-scan' assessment of how the communities are being affected by LKHP during its operation. Conclusions on both, have been based on interviews with the communities during the site visit and future recommendations have been formulated accordingly in this Chapter.

9.1 Scope

Previous community-oriented projects operational during the feasibility study and construction phases of LKHP included MUAJAKI (*Mradi wa Ushirikishwaji Afya ya Jamii*), SEMA-Ki (*Socio-economic Mitigation and Monitoring at Kihansi*) and the CMP (*Catchment Management Plan*). All three projects ended in 2003. The objectives of these projects were to mitigate adverse impacts of LKHP and ensure that the communities had the capacity to take over any initiated activities when the projects ceased. An overview of the project objectives and the residual impacts expected during the operation of LHKP are presented for each MUAJAKI, SEMA-Ki and CMP in Appendix 9 .

With regard to the question of sustainability of the MUAJAKI, SEMA-Ki and CMP activities, Appendix 10 provides three tables, which describe the extent to which activities initiated under the respective projects have been continued by the local governments after project closure.

The timeframe of the on-site audit was brief and not sufficient for an in-depth socio-economic study or project evaluation. Thus, this Chapter can only serve as an overview on the presently prevailing socio-economic aspects and is hence not meant to be taken as a detailed social or poverty audit.

In addition to the fieldwork, the socio-economic analysis included a desk review of the LWCP. The purpose of the desk review was to establish if the LWCP had taken up all social monitoring and mitigation measures as planned in the EMP.

While section 9.2 outlines the methodology followed during the fieldwork in the villages, chapter 10 presents the results of the socio-economic analysis. Section 10.1 contains the results of the desk analysis comparing the LWCP with the planned measures in the EMP and all following sections present the findings of the fieldwork. Section 10.2 deals with public health issues supported under the MUAJAKI programme; Sections 10.3 and 10.4 with water supply and livelihoods issues, which were the focus of the SEMA-Ki programme. Additional aspects raised by the villagers during the interviews are presented in sections 10.5 and 10.6. Section 10.7 contains the results of the interview with District officials and section 10.8 summarizes the findings with a few recommendations.

9.2 Methodology

This Chapter is based on findings from five sample villages selected for inclusion in the scope of this audit of the LKHP. Two of these villages are located in the catchment area of the Kihansi River and three are on the lowland (see Box 2). The village selection was based on the vicinity to LKHP and the expected level of impact from the project. Meetings with government representatives were held in all five villages. For a list of names see Appendix 2 . In addition to these villages, one of the two Districts in the LKHP area was visited. Mufindi District Council was selected as it also features in the LWCP and is crucial for the operation of LKHP.

Box 2 Brief Description of Sample Villages

Mlimba, Kalengakelu and *Udagaji* are the <u>lowland villages</u>. *Mlimba* is the closest business centre to LKHP. It also serves as a train stop for the TAZARA railway. *Kalengakelu* is the next closest village to *Mlimba* and along the road to LKHP, thus a number of LKHP staff reside in this village. *Udagaji* is a sub-village of *Chita*, which was initially only a few households prior to LKHP and has rapidly grown to a sub-village category due its direct vicinity to the LKHP gate.

The two <u>villages in the catchment</u> visted are *Uhafiwa* and *Ukami*. *Uhafiwa* is at the reservoir edge and *Ukami* is at the dam site. With the exception of *Uhafiwa* all the villages visited experienced population increases by influx of migrants looking for income from LKHP. *Udagaji* has had the greatest level of impact from LKHP with regards to migrant population influx. The catchment villages rely mainly on subsistence agriculture for their livelihoods. LKHP has, to a considerable extent, changed the land use patterns in the area by inundating the River, taking arable land from the villagers and by advocating conservation practices that focus on the availability of water for hydropower generation.

The auditors interviewed members of the Village Government and relevant District Council personnel. A pre-formulated checklist (see Appendix 4) aided the information collection in the villages and at the District office. The checklist was developed to cross check the achievements of the three community oriented programmes mentioned above, based on the desk review of relevant project documents. The interviews were semi-structured and provided opportunity for the informants to provide feedback, recommendations, raise concerns and add issues of interest. Personal observation by the auditor provided triangulation of findings and additional results.

10 Findings

10.1 Socio-Economic Aspects in the LWCP

The LWCP translates the recommendations of the CMP into a long-term catchment plan with the aim of ensuring a sustainable catchment management system.

As expressed by the World Bank in the comments received on the draft audit report, the LWCP is expected to play a fundamental role in addressing community related issues arising in the context of the LKHP. The main objective of the LWCP is to extent the environmental and natural resources management planning processes to the wider landscape and upstream areas. Central to the plan's implementation is the full and committed involvement of the communities and as such ensuring joint conservation of the resource base.

In the EMP the LWCP is referred to as a 'long term plan that embodies the EMP and furthers the scope to a landscape wide setting'. While, the LWCP generally addresses the various issues mentioned in the EMP, the scope of geographical coverage, mitigation and monitoring appear to have altered slightly from what was foreseen in the EMP. For example, in the EMP a number of lowland villages, considered to be part of the Kihansi impact zone, were to be included in the LWCP but this has not been the case. Also, certain studies that were to feed into preparation for the LWCP have not been conducted. Table 11 overleaf presents a detailed account of the socio-economic issues in the LWCP (September 2005) compared to what was planned in the EMP.

In brief, the comparison between EMP and LWCP shows the following discrepancies:

- A time delay of about one year in the finalization of the LWCP;
- The nature and extent of involvement of NEMC in the preparation of the LWCP is not clear;
- There has been no mini-catchment study and no reasons for dropping it have been provided;
- Downstream villages of *Mlimba, Kalengakelu, Chisano* and *Udagaji* of *Kilombero* District are not included.

Table 11 Reflection of Socio-Economic Issues in the LWCP

EMP on LWCP	LWCP	Consistency with EMP
Formulation: (pg 9) in 2004 with assistance from NEMC	Final version handed to LKEMP in September, 2005	Time delay
Focus: (pg 9) Socio-economic issues and health in Kihansi River catchment	(pg xiv) Protection of water body in Kihansi dam by addressing socio-economic issues among the inhabitants of the catchment	None
Extent: Larger setting which embeds EMP, a live document subject to revision	Extends EMP updated planning process to wider landscape and upstream catchment areas. A live document subject to review every 5 years	A specific time frame for review has been set
Coverage: (pg 7) LKEMP project area including *Mlimba, Ukami, Uhafiwa, Udagaji, Chisano* and *Kalengakelu* villages. Area is outside LKHP	(pg 4) Includes the Kihansi River basin with 10 sub-catchments. There are 14 villages in two districts *Kilolo* and *Mufindi.*	Villages of *Mlimba, Kalengakelu, Chisano* and *Udagaji* of *Kilombero* District are not included as they are on the lowland. THE LWCP adopts all villages from the CMP.
Mitigation in Catchment: (pg 63) a) Human health programme b) Natural resources (includes water resources) management programme	(pg 156) List of activities for four components of mitigation provided; a) Conservation farming practices adopted b) Improved livelihood options available c) Biodiversity and Environment Services maintained d) Improved enabling institutional and policy environment	None
Mitigation in the Gorge ecosystem: (pg 71) Mini-catchment study findings to be integrated into LWCP		No mention of mini-catchment study findings
Links to other programs: (pg 80) LKEMP and the EAMCEF	EAMCEF, World Bank and UNDP emphasised as funding sources	Additional funding sources e.g UNDP included
Monitoring in the Catchment: (pg 82) Establish a baseline with recent satellite or aerial imagery for the area. Study to include ground truthing and a socio-economic study of driving force behind changes.	(pg 26) Use of a satellite image of 2003 to determine land use and land cover changes from 1999 classification map.	None

During the process of preparation of the LWCP, Participatory Rural Appraisals (PRAs) were conducted in 7 villages[7]. The main aim of the PRAs was to feed into the LWCP and enable long-term conservation. The PRAs revealed that the main threats to sustainable catchment management are the lack of financial and technical resources to conduct conservation activities. In response to this LKEMP prepared a handbook of guidelines for the preparation and implementation of sub-projects. This handbook outlines the process whereby villages can apply for small grant funding (via the Districts) to LKEMP. These grants are only available for communities in the LWCP focal area, i.e. the 14 villages in both Kilolo and Mufindi Districts.

Our findings on the continuation of MUAJAKI, SEMA-Ki and CMP activities are presented in the following sections.

10.2 Public Health

The MUAJAKI project was geared towards addressing health related impacts associated with the LKHP, in particular prevalence of malaria and sexually transmitted diseases (STDs). One of the mitigation measures provided through MUAJAKI was public health education. The implementing bodies were the health departments in the responsible Districts.

In both catchment villages, *Uhafiwa* and *Ukami,* primary health attendants were trained by MUAJAKI on how to monitor malaria cases including malaria mortality. This is no longer done. Public education on how to prevent malaria is provided regularly including use of mosquito nets and prevention of the spread of vector habitat by local government clinical officers. Mosquito nets are available for a subsidized price to women for Tsh 1,500/- per net (including “ngao”, a repellent). The regular price is Tsh 3500/-.

We were told that in *Ukami* and *Uhafiwa* the District has taken over the following activities related to health:

- Maintaining the running cost of the village dispensary including quarterly supply of medicine;
- Mother and Child Healthcare (MCH) education but at a limited level due to insufficient staff and technical support;
- Maintenance and supply of equipment used for testing malaria and STDs and HIV;
- Health education conducted by clinical officers for local community and individuals on STDs and HIV. In *Ukami* an educational session is conducted for one particular disease every working day. In Uhafiwa village no such education has been provided since the phasing out of MUAJAKI.
- In Ukami condoms are distributed for free by the village government dispensary with subsidies from the District Council. In addition, condoms can

[7] 2 from Kilombero district on the lowland (Chita and Mlimba), 3 villages from Kilolo district (Ng’ungula, Masisiwe, Boma la Ng’ombe) and 2 villages from Mufindi district also on the catchmnt (Igeleke and Mapanda).

be purchased in local shops for Tsh 100/- per packet. In Uhafiwa purchase is the only option.

- A villager in *Uhafiwa and Ukami* has to pay Tsh 5000/- per year to become a member of the dispensary eligible for treatment. This membership does not include cost for drugs. Alternatively Tsh 1000 have to be paid for every visit to the public dispensary to receive a consultantion. The majority of the villagers are only able to afford the latter option.
- Data on malaria cases is being compiled weekly, monthly and quarterly by the dispensary as a routine activity. This occured even prior to the project.

In the lowland villages health issues are not highlighted as part of the impacts associated with the operation of LKHP. However, the audit team understands from village meetings that health issues prevailing among communities in the catchment are even more pronounced in the lowland. This might not be only due to the presence of LKHP. Other major contributing factors might be the overall better developed infrastructure in the lowland villages, for example the road to Ifakara, the JKT (Jeshi la Kujenga Taifa) camp at *Chita* and the Tazara station in *Mlimba*.

During the construction phase of LKHP health services in these villages were to be improved as follows:

- In *Mlimba A* a dispensary was built and the cost of services were provided by LKHP. The local government is presently managing this dispensary.
- In *Kalengakelu* village a dispensary was constructed and funded by MUAJAKI.
- *Udagaji* has no dispensary but treatment is currently available from the TANESCO dispensary at the Lower Kihansi Hydropower plant.

In the lowland malaria is endemic particularly in the rainy season. This has always been the case, even prior to the construction of LKHP. Due to the severity of the problem monitoring of malaria cases has always been a government activity. Measures taken to reduce malaria cases with MUAJAKI support include health education, provision of mosquito nets and treatment.

The second most prevalent illness after malaria is typhoid associated with the shortage of clean water, improper sanitation and the tendency to drink water, which has not been boiled. The lack of sufficient sources of clean water has forced most people to use water from shallow wells that have been subject to contamination by the shallow latrines. The problem is worse during rainy seasons when most people leave their homes and establish temporary settlements in the agricultural areas, far from sources of clean water.

MUAJAKI conducted educational sessions on STDs and HIV in the lowland communities. Some members of the communities were trained to become counsellors and peer educators. However it has been reported that they are not using their education to help others. We were told that the problem of HIV is now becoming more serious and the village has no facilities to deal with it.

MCH is also a problem for all villages on the lowland. The dispensaries do not have adequate facilities to handle birth complications. The District Hospital at

Ifakara town is the closest medical centre far from the LKHP area to which there is no public transport from any of the other villages. Private transport is available at a price of Tsh 72,000 for fuel and has to be paid up-front before one is taken to the hospital.

On the lowland, cost sharing arrangements for health services differ slightly from that in the catchment villages. The costs are: Tshs 200/- for registration; consultation and purchase cost depend on ailment. Drugs have to be brought from the pharmacy. In *Udagaji* villagers attending the Kihansi dispensary have to incur similar costs to those of *Mlimba* and *Kalengakelu*. In contrast to the catchment villages there is no membership programme on the lowland. Likewise there are no subsidised nets for pregnant mothers as all nets are sold for Tshs 3500/-.

All down stream villages report the absence of proper sanitation facilities. We were able to verify that only few people have adequate latrines that were constructed by the MUAJAKI project. After the project no efforts were made to continue the initiative to increase access to improved latrines. As a result, shallow pit latrines are commonly used, which can potentially contaminate water used for domestic purposes.

10.3 Water Supply

The SEMA-Ki project assisted with supply of clean water and livelihoods activities.

In *Mlimba A,* one of the lowland villages, LKHP constructed five deep wells that use electric pumps to supply water to the villagers and the LKHP staff living in *Mlimba A*. A water user group was formed to manage the water supply and to collect Tsh 10/- per bucket to cover the running cost, including the electricity bills. In practice the smooth operation of wells has been hampered by lack of good governance in the water user groups. Despite the collection of fees, the money has not been used to pay the bills. As a result TANESCO had to disconnect power to some of the wells as a disciplinary action, leaving only two wells operational. However, even for those in operation no payments have been made and the current debt stands at 25 million Tshs. With only two wells operational water supply has become a problem in *Mlimba A*. This is exacerbated by the rapid increase in the population due to migration and high birth rates. The shortage of water has led to increased incidence of diseases such as Typhoid and Diarrhoea which rank second and third in the number of cases in *Mlimba A* in the village health records.

In *Kalengakelu* village water is obtained from wells using hand pumps constructed by SEMA-Ki and other wells constructed by the District Council through the Village Government. The current supply of water is insufficient to sustain the population in the village that amounts to a total population of 6449 people.

Similarly in *Udagaji,* the villagers get water from wells that use hand pumps, also constructed by SEMA-Ki and District Council through village government. Water supplied by wells is not enough to sustain the population of 1535 people. It was reported to us that most of the villagers obtain water from streams flowing from the Udzungwa Mountains and water from wells supplements their requirements.

In the catchment villages water is obtained only from streams. No well was constructed, either by SEMA-KI nor the District Council. In *Ukami* village water is reportedly a significant problem as there are few permanent streams compared to *Uhafiwa*. The villagers depend on two permanent springs found down the valleys, which are not adequate and the level of safety for domestic use is questionable. Though water availability in *Uhafiwa* is not a problem, cleanliness and safety of the stream water is uncertain.

10.4 Livelihoods

Subsistence agriculture is the principle income generating activity for both catchment and lowland villages. Crops produced include rice, maize, cassava, peas, groundnuts, and finger millet. Part of the produce is sold to pay for other non-agricultural food products (e.g, sugar, salt, tea) and other requirements like hospital expenses. The market for these crops is limited particularly in the catchment due to the lack of infrastructure and transport. Villagers from *Uhafiwa* carry 20 - 30 kg of maize, beans or millet over 40kms down the escarpment to *Chita* to sell it at a price between Tsh 2000 to 5000.

Access to markets is less of a problem in the lowland villages as traders come to the villages to buy crops. In *Kalengakelu* village the District introduced sunflower as a cash crop. There is also an Irish Aid supported livestock project. Natural resource exploitation through charcoal burning, timber harvesting and fishing was reported to us as common.

In the catchment villages alternative sources of income are limited. Woodlots were introduced by SEMA-KI and CMP as a source of income. Reportedly, very few people can afford to buy the seeds (Tsh 500/- per seedling) and the concept of tree planting is still not well adopted as concept of preserving the environment for future generations. Thus, we were informed that exploitation of natural resources continues in the area.

10.5 Employment Generation and Community Relations

The EMP (pg. 57 onwards) advises that TANESCO and other implementing agencies should uphold a ‘locals first’ policy when employing new staff. This policy should give preference to members from the local community provided they have the skills required for the job.

Upstream villages report that there has been no employment generation through the LKHP. Villagers in the downstream communities acknowledge the fact that there was employment generation during the construction phase but report that it has decreased substantively post construction. We were able to confirm that occasional labourers are hired from downstream villages to maintain, for example, the re-vegetation efforts along the Kihansi road. Various sources confirm that the post-construction employment effect is small as the majority of TANESCO staff has been brought in from other power plants elsewhere in Tanzania. This is perhaps not surprising as the operation of a hydropower plant needs specialised skills and training.

The EMP recommends the inclusion of community relations programmes in the social mitigation measures listed for the LKHP works site (p.72).

We understand that while there is a TANESCO representative responsible for environmental, health and safety issues relevant to resident staff, there is no contact person for communities. It was reported that the contact between LKHP and villagers in the adjacent communities is minimal, in particular with regard to the two upstream villages visited as part of this audit.

All three projects suggested that a Kihansi Management Committee be established to deal with community activities during operation of LKHP. However this was not set up. Hence the communities feel that they do not have a platform of discussion with the LKHP.

10.6 Land Issues and Lack of Electrification

Villagers resettled during the LKHP construction phase in the *Udagaji* village area were compensated for crops and houses through the relevant Local Authorities. During the site visit the communities raised concern for the discriminative attitude which allows TANESCO staff to farm on land that they had to give up in the name of 'conservation'. Furthermore, the villagers feel that the population influx triggered through LKHP has decreased land availability and increased land conflicts.

A justification for the allocation of farm land to TANESCO staff on former village land is not provided in any documents reviewed by the audit team. It would rather seem rational that TANESCO staff, which has purchasing power, would contribute to the economies of the local farmers by buying their produce rather than farming themselves on former village land. This situation seems to create tensions between local population and TANESCO staff.

The lack of electrification was aired as a concern in all villages visited. Only one sub-village, *Mgugwe* of *Chisano*, close to the previous MUAJAKI camp is electrified with power from LKHP. This village which was not included in the EA, has attracted a number of LKHP staff who do not reside in the camp and thus TANESCO has electrified this village.

It is understandable that the sight of power lines going through a village to electrify a distant municipality in a scenario where power is unavailable locally leads to discontent. The complexities of rural electrification and the lack of economic viability for TANESCO to electrify individual villages are known. This problem would need to be addressed on a national scale and not only at Kihansi. For example the Rural Electrification Fund set up under the Ministry of Energy and Minerals could prioritise those villages in vicinity of hydropower plants, as a means to decrease tension and to generate local goodwill and support.

Allegedly during campaigning for the LKHP the villagers were promised by NORPLAN and District officials that their villages would be electrified. Although this may generate goodwill in the short run, it is likely to turn into the opposite in the long run.

10.7 Findings from Mufindi District Council

The District Council had close contact with LKHP from project feasibility through to operation. The consultant, NORPLAN, on behalf of the client, TANESCO, ensured all progress reports of relevance from the feasibility and construction phases were copied to the District Council. In particular reports from the social oriented projects were sent as it was the intention that these were to be handed over to the District.

Since the closure of the community oriented projects, the District has taken over the administration of the LKHP constructed dispensary and teacher accommodation at *Uhafiwa*; and the health staff quarters at *Ukami*. However, the following difficulties were reported to us:

- Financial constraints: The funding at the District is not sufficient to continue the activities initiated under the MUAJAKI and SEMA-Ki projects. Mufindi District has 132 villages of which only 14 are within the area of concern to LKHP. The District receives approximately Tshs 3 million from the Central Government and collects approximately Tshs 4.5 million from local revenue to carry out all its activities. The budget allocations presented in the EMP for Local Authorities (US$ 30,000) must have been notional allocations as they were not effected to the Districts.
- Technical constraints: District staffing in the two wards within the Kihansi area is inadequate.[8] The District has recently signed an agreement with the Tanzania Social Action Fund (TASAF) but no funding has been forthcoming to date.
- District priorities: HIV/AIDS in Mufindi is considered especially important on the tea and timber plantations where there are large numbers of migrants living in camps and thus efforts to combat the problem are focused in these areas. Another development suspected to have increased HIV/ AIDS cases is the road through the District. LKHP is not considered a main contributor to the problem.

The District brought forward the following recommendations:

→ LKEMP and TANESCO to meet with the respective communities and District to draw up action plans for sustainable management of the catchment.

[8] Natural Resources (3); Health (8); Community Development (2) and Agriculture and Livestock Development (4). The two wards are Kibengu and Mapanda. It should be noted that there are more than 14 villages in these two wards and that the district staff are for the wards and not restricted to the 14 villages.

Since the workshop held in July 2003 nothing has been forthcoming from LKHP. District Officials would like more regular meetings with LKEMP and TANESCO.

→ LKHP should provide education, incentives or alternative income generating activities to the communities in areas where farming is detrimental for the dam and reservoir. During the SEMA-ki project people were told not to fish, or to plant eucalyptus trees. However alternatives need to be provided, in order for these recommendations to be followed.

10.8 Summary

It is reiterated that the time available during the audit site visit precluded gathering sufficient information for an in-depth socio-economic appraisal. Thus, the information presented in this chapter and the conclusions made cannot be generalized for all the villages in the LKHP area or the LWCP focus area. However, the findings correspond to concerns raised by the respectice communities visited and related to the MUAJAKI, SEMA-Ki and CMP programmes that justified their operations during LKHP feasibility and construction.

The following broad conclusions can be made from the socio-economic analysis:

- There is poor continuance of activities initiated by the socio-economic programmes of the construction phase as the District governments are not capacitated to do so.
- The communities were not informed sufficiently on the impacts of the various components of LKHP, i.e. feasibility, construction and operation and more specifically who is responsible for what.
- There is no platform for community concerns during the operational phase of LKHP.
- Community expectations of the LKHP have not been met due to falsely raised hopes during feasibility and construction.
- Inconsistency on the issue of land conservation by TANESCO resulted in ill feeling on the part of the community.
- There was insufficient awareness raised on how to cope with impacts of a hydropower plant development in the area.
- Health issues are still an important area to be addressed, particularly HIV/AIDS and malaria in both lowland and catchment villages.

To address these discrepancies the following corrective measures are recommended:

→ A conservation plan that focuses on the lowland communities would mitigate environmental degradation in the lowland.

→ Inclusion of lowland villages in the LKEMP small grants scheme.

→ TANESCO needs to establish institutional responsibility to deal with community concerns related to LKHP.

Part 4 - Recommendations and Conclusions

11 Recommendations

Based on the audit findings presented in the preceding Chapters, the audit team brings forward recommendations for remedial action. The recommendations have been highlighted throughout the report and have been summarised in this chapter in bullet form.

For additional information, the reader is referred to the corresponding Chapters.

Appendix 10 contains a table with all recommendations, a column for comments, date and type of action taken. This is meant to facilitate the client's follow-up.

11.1 Kihansi Gorge Ecosystem

11.1.1 Artificial Spray System

- → Introduction of a double tank system for all three spray wetlands;
- → Measurement of pressure and installation of filters;
- → Mechanism to allow rapid purchase of spare parts;
- → More frequent pressure checks on each sprinkler during the rainy season;
- → More frequent cleaning of sedimentation ponds;
- → WD should abide with the Water Act of 1974 Section 15;
- → Introduce sprinkler precipitation measurement into the monitoring regime.

11.1.2 Gorge Maintenance Infrastructure

- → Improve safety conditions of the Gorge maintenance;
- → Conduct EIA for all planned research related infrastructure prior to the finalization of their design plans.

11.1.3 Habitat Monitoring

- → Further training of the Gorge Technicians;
- → Reports of studies and consultancies should be routinely shared with the RAMPO office;

- → Give RAMPO more flexibility to take decisions relating to day to day management of activities in the Gorge, e.g. control over sufficient funds to purchase spare parts;
- → The water quality meter should be repaired to facilitate measurement of turbidity;
- → Make provisions for periodic testing sediments, BOD, COD, and bio-monitoring and monitoring of organic substances used as pesticides or fertilisers should be made;
- → Repair and replace RBWO and LKEMP data loggers;
- → Conduct Chytrid studies using 'swabbing' technique on amphibians to investigate prevalence of Chytrids in the Gorge.

11.1.4 Gorge Access and Safety Protocol

- → Improve enforcement of bleach foot bathing procedures;
- → Take preventive measures to address theft of equipment.

11.1.5 Ex-situ Captive Breeding Programme

- → Ensure wider and timely sharing of information gained from Captive Breeding programme.

11.1.6 Kihansi Scholarships

- → Establish database and website to ensure accessibility of information to all parties;
- → Extension of scholarship programme to include funding and activities for conservation education at primary and secondary schools in LKHP adjacent communities.

11.2 Vegetation

11.2.1 Size of Spray and Vegetation Changes

- → Further study is required to monitor if there are changes in vegetation characteristics with the current flow regime.

11.2.2 Vegetation Monitoring

- → The RAMPO should be trained further particularly on aspect of plant identification.

11.2.3 Related Studies

- → Establishment of the baseline and scientific protocol on epiphylls monitoring.

11.3 Kihansi River Hydrology

11.3.1 By-pass Flow

→ Explore possibilities of using rectangular open channel to countercheck flow from the bypass pipe;

→ RBWO should download data from the loggers on monthly basis for effective monitoring water flows in the Kihansi river;

→ RBWO need to improve reading and collection of data from the river gauge station by providing transport to the responsible staff;

→ Staff gauges installed at river stations need to be used to calibrate the data loggers;

→ Any gauging stations currently not functioning should be rehabilitated and a reliable and timely routine maintenance system established;

→ TANESCO and RBWO should exchange hydrological and hydraulic data on the Kihansi river on real time basis as proposed in the EMP.

11.3.2 Hydrological Monitoring

→ Specific training is required for the RAMPO to carry water quality monitoring;

→ The river water need to be tested against sediments, BOD, COD, and also bio-monitoring e.g levels of phytoplankton;

→ Research and Consulting reports need to be routinely shared with the RAMPO office;

→ Field testing of water quality need to follow closely the Tanzanian Water Utilization Regulation. This will include monitoring of organic pollution introduced artificially and organic pollution of natural origin.

→ RBWO should repair any non-functioning measuring instruments and implement a timely routine maintenance practice. The reading of gauges needs to be undertaken regularly.

→ Training of RBWO staff at site needs to be provided as foreseen in the EMP.

→ The monitoring of diversions for the Kihansi domestic water supply and spray wetlands by RBWO needs to be done in a systematic manner.

→ The financial viability of RBWO monitoring needs to be reviewed.

11.3.3 Monitoring at the Dam

→ As proposed in the EMP it is important to have a standard procedure for monitoring seismic events and structural stability of the dam, standard procedures for monitoring sedimentation rate in the dam and release of sediments from dam during flushing operations.

→ Repair dam monitoring tools, e.i. piezometers, presently not functioning.

11.3.4 Hydrological Modelling

→ Correct inconsistencies in the reporting on the total number of gauging stations;

→ A more consistent presentation of responsibilities/ownership of the various gauging stations in the reports would be desirable;

→ Verify to what extent foreign technology can be replaced by simple, locally available technology so that parts and spare parts for various equipment can be obtained at more reasonable prices;

→ Consider, a change in management structures, favouring those closer to the operations as it may yield efficiency gains, for example recruitment and placement of resident technicians at the site.

11.3.5 Other Issues

→ Clarify (or delete if not applicable any more) the requirement in the EMP that TANESCO and RBWO should exchange hydrological and hydraulic data on the Kihansi River on real time basis.

11.4 Erosion, Fire Control and Waste Management

11.4.1 Erosion and Fire Control

→ There should be standard procedures for monitoring erosion and re-vegetation of the excavated land;

→ There is an urgent need to stringent prevention and control of fires; in this context the legitimacy of cultivation of land surrounding LKHP area by TANESCO staff should also be reviewed.

11.4.2 Waste Disposal at Lower Kihansi Hydropower Works Site

→ There is need to have an Engineer or Technician responsible for environmental mitigation measures at the LKHP work site;

→ There is a need to establish solid waste standard monitoring procedures, which will assist to improve solid waste management at the work sites;

→ Liquid waste from the camp dispensary and clinic need to be tested for appropriate treatment before entering to the domestic water treatment system.

11.4.3 Solid Waste Disposal in the Gorge

→ Waste disposal should be treated as a long-term issue and it is reasonable to expect that at least non-burnable, non-biodegradable waste be carried outside the Gorge. Certainly, all plastic waste should be carried out. This policy needs to be made clear to staff and visitors. Tins could be washed, collected, and another porter hired to carry down such a load.

11.5 Occupational Health and Safety

11.5.1 Compliance with TANESCO Health and Safety Policy

→ Any deficiencies from the company policy described in Chapter 7 should be rectified;

→ Institutional responsibility for Health issues needs clarification;

→ Reports from Field Office need swift follow-up action from Headquarters, or otherwise decision making responsibility decentralized in order not to delay important security measures.

11.5.2 Safety Management and Control System

→ The managerial procedures for safety concerns need to be revised to provide for more effective and direct response to the various security concerns.

→ Pest control measures should be taken.

11.5.3 Health and Safety Issues in the Gorge

→ The suspension bridge at the bottom of the Gorge needs to be strengthened and made more stable;

→ The latrines need to have a basic roof and each "squatting plate" should be made stable;

→ The hole of the pit latrine needs to be kept covered in the interests of cleanliness and disease control;

→ A first aid kit needs to be kept in the Gorge, as does a stretcher, thus facilitating evacuation. Staff needs to be given basic training in First Aid;

→ The RAMPO and Gorge Technicians be made aware of the symptoms of Rickettsia and medical personnel associated with the project also receive this information, and on treatment;

11.6 Institutional Aspects

11.6.1 Monitoring, Reporting, and Training

→ The EMP should be adjusted to simplify the reporting system;

→ The EMP monitoring system is not followed in practice and may hence need to be reviewed;

→ NEMC/LKEMP should prepare an annual monitoring report summarizing all monitoring data collected in the Gorge Ecosystem and disseminate widely, including to the public in LKHP locality (this requires a public version in Kiswahili for non scientists).

11.6.2 Coordination

→ A review of the institutional set up of the LKEMP with a view of full inclusion of all relevant stakeholders and more complete and timely sharing of information;

- → Public disclosure of environmental monitoring results and studies undertaken by LKEMP. The public includes not only the national and international research community but also village communities around Kihansi and elsewhere in Tanzania.

11.6.3 Ultimate Responsibility for Mitigation and Monitoring

- → Long-term institutional responsibilities for the Kihansi area to be clarified;
- → The process of granting the land title to be finalized.

11.6.4 Decommissioning

- → TANESCO, involving other stakeholders, is encouraged to carefully plan and set aside funds for decommissioning incorporating lessons learned and best-practise from other projects.

11.7 Socio-Economic Aspects

- → In addition to the LWCP, a conservation plan that focuses on the lowland communities would mitigate environmental degradation in the lowland;
- → The establishment of a platform to deal with community concerns related to LKHP.

12 Conclusions

This audit has shown that the majority of mitigation and monitoring measures specified in the EMP have been implemented within the so far elapsed 14 month implementation period.

The RAMPO and her field team are making serious efforts to maintain and monitor the Gorge Ecosystem. This is complemented by more comprehensive monitoring studies carried out by consultants or research institutions. A vast amount of information has been collected through the various consultancies and studies, which all have the potential to contribute to a greater and clearer understanding of the complex Kihansi Gorge Ecosystem. RBWO has been active in its role as the body charged with monitoring the Water Right. TANESCO has responded to some of the concerns raised by LKEMP, e.g. the correction of the amount of bypass flow. In addition TANESCO has largely followed its own corporate health and safety procedures with a few exceptions, which need to be corrected.

Despite these achievements, there is room for improvement.

The long-term success of the plans to conserve the Kihansi Gorge Ecosystem is dependent on a management plan that will involve all of the stakeholders, set clear targets and responsibilities as well as accountability. Data and information collected need to be made available for analysis and an institutional mechanism for analysis set in place.

Presently, it is not clear how the information from the various specialised reports feeds into a revision of the mitigation measures. This audit found that the current management system of the Lower Kihansi project area is not efficient due to a lack of a monitoring plan with verifiable targets; periodic reviews of monitoring information and studies to generate feedback into future decision making. There is evidence for a delay in response and decision-making as well as a lack of information sharing and limited accessibility of data and public information.

There is a tremendous range of scale involved at Kihansi, where issues range from a large scale (management of the catchment) down to micro-habitat (spray dependent habitats), and stretch over at least two regions; Morogoro and Iringa. We feel that given the complexity of the situation and the scale of impacts involved, institutional coordination, as well as commitment and ownership of the institutions needs improvement.

There are two equally important and interdependent strategies as far as the conservation of the KST is concerned. These are *ex situ* conservation efforts (captive breeding) and *in situ* efforts, mostly focussed on rehabilitating the spray dependent habitats in the Gorge. The latter also had to focus on matters relating to the Chytrid Fungus. Its appearance was noted as possibly a threat, but had not materialised at the time of the initial planning for IREM and LKEMP activities. This shows the importance of flexibility and timely response in the management system.

The LKHP is an example of the fine line between economic development and environmental conservation. Consequently there are many controversies in the LKHP. The planned expansion of the sprinkler system, although desirable from a point of view of maintaining the Ecosystem, is controversial with regard to the abstraction of water from either the bypass flow or other sources.

The KST is currently in the position of a single species totally dependent on artificial habitat management and captive breeding. The high costs involved, both financial and technical, at the national as well as international level, indicate the complexities of the tradeoffs over use of biodiversity and water resources.

Should the Spray Toad population recover, it might be dependent for its continued existence on the sprinkler system that requires constant attention and maintenance. Hence, an important long-term issue, which needs attention is the sustainable financing of the mitigation and monitoring programme in the Gorge and the Catchment by TANESCO and the decommissioning of dam. Donor dependency has presently blinded the view for the need to take responsibility.

Appendices

Appendix 1 Terms of References

A. Introduction

These Terms of Reference (ToRs) are for the selection and employment of a consultant to undertake Environmental Audit of the Lower Kihansi Hydropower Plant in Tanzania. The study is supported by the Lower Kihansi Environmental Management Project (LKEMP), funded by the World Bank/International development Association (IDA).

B. Background

The Lower Kihansi Hydropower Plant (LKHP) was constructed during the 1990s and became fully operational in 2000. The scheme incorporates a 25 m high dam which diverts water to an underground power generating station, returning water to the river about 6km downstream. As a result of this river diversion, there has been a significant impact on the aquatic, riparian and adjacent ecology of the area immediately downstream of the Kihansi Reservoir. Here, the Kihansi River runs through the Kihansi Gorge and has a number of waterfalls that sustain a unique microclimate, forest ecosystem and series of spray wetlands. These impacts have assessed to be globally significant. A variety of other more regionally or locally significant environmental impacts have resulted, arising from the construction of infrastructure, roads, communication networks and associated works at Kihansi.

In addition to environmental impacts, various health and social impacts have been caused which has been the subject of previous specific short term mitigation programs. These were the IREM (Immediate Rescue and Emergency Measures) Project, MUAJAKI and SEMAKI programs which dealt with Gorge ecological issues, public health and social issues respectively.

The Lower Kihansi Environmental Management Project (LKEMP), a medium and long-term initiative, is under the auspices of the National Environment Management Council (NEMC), in the Vice President's Office. The LKEMP main objectives are to put in place a series of medium-term measures to ensure the long-term conservation of the Kihansi Gorge ecosystem and upstream catchment areas; and at the national level, to support the development of a co-ordinated and consistent legal and institutional framework for environmental and water resources management, and strengthening of the ecosystem monitoring and assessment functions of the environmental institutions. The project has four components:

- Habitat and species conservation and management
- Establishment of final water right
- Implementing an updated environmental management plan
- Institutional strengthening

Under component 3 the LKEMP has prepared an Updated Environmental Management Plan (EMP) with a package of mitigation steps which are now under implementation in conjunction with the ecosystem monitoring and conservation program.

C. Objectives of Consultancy

The principal objective of the Environmental Audit (EA) consultancy services is to assist LKEMP/Government of Tanzania verify whether the Environmental mitigation and monitoring measures recommended under the Updated Environmental Management Plan (EMP) are achieving their intended objective of maintaining a sustainable ecosystem in the Kihansi Gorge and its environs and recommend the best way forward.

D. Scope of Work and Activities

Specifically the consultant/s shall:

i. Undertake Field verification and surveys to ascertain the validity of the various management reports;
ii. Determine the nature and extent of all environmental areas of concern (including occupational health and safety) at the hydropower facility.
iii. Undertake Field verification of socio-economic and public health aspects in three up-stream (catchment area) and two downstream villages

iv. Identify and justify appropriate measures to mitigate the areas of concern, provide estimates for the cost of the measures, and recommend a schedule for implementing them. This work will entail a systematic, documented verification process of objectively obtaining and evaluating evidence to determine whether specified environmental activities, events, conditions, management systems, or information about these matters, conform to audit criteria.

v. Identify any possible bottlenecks and ways in which short-comings can be resolved, including improvements to the mitigation and monitoring programs, modification of institutional arrangements, and provide advice on financial management.

Audit criteria may include but are not limited to:

- Industry Codes of Practice
- Specified organisational requirements, such as company environmental policy
- The Updated Environmental Management Plan for the Lower Kihansi Hydropower Project
- National and local laws
- Conditions of licences, works approvals and exemptions
- International treaties, protocols or other obligations

E. Desired Outputs

There will be four outputs generated by this assignment: an inception report; progress report, draft report on the EA; and the respective final report.

1. **Inception Report:** The consultant will prepare and submit an inception-report on 9 September 2005 . The LKEMP PMU will provide comments within the following two weeks.
2. **Progress report:** A summary of progress made so far including any limitations on delivery of the work
3. **Draft Final Report:** This document should be developed and submitted to LKEMP within 90 days after the submission of the inception report . LKEMP would provide written comments within two weeks.
4. **Final Reports:** This document should be submitted by the consultant to LKEMP within two weeks of receiving written comments.

In accordance with the scope of work outlined in section D above and the desired outputs described in this section, the Audit Report will include the following sections:

(a) **Executive summary**: A concise discussion of all environmental and occupational health and safety areas of concern, recommended mitigation measures and their priority, the cost of mitigation, and a schedule for compliance.
(b) **Project Description**: A concise description of the project, including both past and current operations. The description should focus on project components with potential environmental and occupational health and safety concerns.
(c) **Regulatory Setting**: Details of Tanzania, local, and any other applicable environmental and occupational health and safety laws, regulations, guidelines, and policies as they may directly pertain to the hydropower facility.
(d) **Audit Procedure**: Details of the approach used to conduct the audit, including the audit protocol. This section shall include specific information relating to historical research and records review, interviews, site inspections, and other aspects of the audit procedure. This shall include,

but not be limited to, a review of vegetation monitoring, toxicological and other studies conducted at Kihansi. Particular attention shall be paid to verifying the bypass flow being released from the Kihansi Reservoir to sustain environmental values in Kihansi Gorge.

(e) **Areas of Concern**: Details of all environmental and occupational health and safety areas of concern. The areas of concern shall be discussed in terms of both existing facilities and operations and contamination or damages due to past activities.

(f) **Mitigation**: Specific details of the appropriate mitigation measures and why they are necessary, and a discussion of whether the appropriate mitigation measures are readily available in Tanzania. This shall be based on an Action Plan agreed at the exit interview addressing those issues not conforming with good practice or requiring improvement.

(g) **Costs and Schedule**: Estimates of the cost of implementing the mitigation measures and a schedule for their implementation. Cost estimates are to be based on Tanzanian conditions. Schedules should be recommended within the context of any planned capital expenditures for the facility.

(h) **Annexes**: To include references, copies of interview forms, any details regarding the audit protocol not already included in (d), and data obtained during the audit but not included directly in (e), (f) and (g) above.

F. Reporting Requirements and Time Schedule

The consultant will report to the National Project Coordinator (NPC) who will guide the day to day implementation of the consultancy and provide relevant administrative and technical support.

The proposed tentative timetable is:

Start of work (signing of contract)	10 June, 2005
Inception Report	9 September, 2005
Progress Report	27 September, 2005
Draft Final Report	15 October, 2005
Final Report	2 week after receipt of
comments by the client	

G. Data and Support

The project will provide limited backstopping and technical support services to the consultant. The project will organize meetings with Tanzanian individuals and institutions as it may deem necessary. The project will avail relevant available background materials and reports to the consultant, or assist to obtain information from other sources if necessary.

H. Desired Outputs

The outputs of this consultancy will be an Environmental Audit report detailing the items listed under section E above.

I. Consultant's Qualifications

The consultant will have extensive and broad based experience in conducting environmental audits, preferably in East Africa. They should be familiar with relevant policies and regulations applying to environmental audit and environmental impact assessment, both nationally and internationally.

Appendix 2 List of people interviewed

Name	Position
Dr. Wilfred N. Sarunday	National Project Coordinator LKEMP
Ms. Anna Maembe	NEMC
Mr. Juma Kayera	Assistant Director, Wildlife Division
Mr. Benjamin Andulege	Game Officer, Research and Training, Wildlife Division
Mr. David Ngula	Manager Research & Development, TANESCO
Mr. Stanislaus Kizzy	Senior Hydrologist, TANESCO
Mrs. Devolent Mtui	LKEMP-RAMPO
Mr. Joseph Kerario	Head Technician, LKEMP
Isaya Luena Person Kalenga Bakari Swaki James Mtenga Amberson Kalenga Michael Mwambona Sunday Njogoro	Gorge Technicians Welding section Carpenter
Julius Chomolla	Acting Plant Manager, TANESCO
Mr. Lymo	TANESCO, Kihansi, Civil Technician, Maintenance, in charge of Water Treatment Plant, Social Club and Water Management
Makaba Rubida	Villager, River Gauge Recorder, RBWO
Mr. Luhumba	Gauge reader– Civil Technician, TANESCO
Mr. Onais Rubida	Villager, River Gauge Recorder, RBWO
Mr. Mallele	Health Officer, TANESCO dispensary
Uhafiwa Village Meeting	
Charles Mkumi	Chairman
Isaya Mhemu	Executive Officer
Amelye Chogo	Village Government Member
Edward Lubida	Village Government Member
Measomi F. Mheni	Environment Chairman
Charles Msombe	
Kwalesia Mgimba	Dispensary Doctor
Ibradi Mheni	Village Chairman
Michael Kifuoga	Servant T.A.G
Nzita Mheni	Primary Health Attendant

Henry Lubida	
Frank Lyakungi	
Charles Mkumi	Chairman
Isaya Mhemu	Executive Officer
Amelye Chogo	Village Government Member
Edward Lubida	Village Government Member
Measomi F. Mheni	Environment Chairman
Henry Lubida	Catechist
Frank Lyakungi	M.A.K
Jackson Gazulo	Village Government Member
Nebioti Mhani	Village Government Member
Lukelo Chogo	Village Government Member
Mathias Kahise	Village Chairman
Tumwidinaje Mheni	Village Government Member
Legneth Gazulo	Village Government Member
Lidia Lyakungi	Catechist
Josephat Mheni	Village Government Member
Augustino Mheni	Village Government Member
Nestory Lubida	Village Government Member
Daniel Kaguo	Village Government Member
Pius Mheni	Village Government Member
Enock Peter	Village Government Member/Craftman
Elyuta Mheni	Village Government Member/Farmer
Odeni Uggi	Village Government Member
Salum Uggi	Village Chairman
Mlimba A Village Meeting	
Daniel Mkula	Village Chairman
Jackson Nkonkhela	Village Executive Officer (VEO)
Japhet Mwansasu	Member
Jovila Mfyomole	Member
Benjamini Undole	Health representative
Fikile Kibweja	Sub-village Chairman
John Mbekelembe	Member
Khassim Kitale	Member
Mage Minja	Member
Santina Songoro	Member
Halidunda	Sub-Village Chairman
Avelino Mnofuwasenga	Assistant Head Teacher
Menard Kidegelimba	Member
Osmund Ndunguru	Sub-Village Chairman
Flora Sanga	Member
Francis Chimwaga	Member
Fortinivo Tulutuhu	Member
Alberto Pilla	Sub-Village Chairman
Edgar Sweveta	Member
Rashidi L Jonewa	Sub-Village Chairman
Kalengakelu Village Meeting	

Deodatus Mgungusi	Village Chairman
Danistan Lyakwipa	VEO
Betresia Mhala	Member
Michael Makuye	Sub-Village Chairman
Faudeni Ngondo	Sub-Village Chairman
Mustafa Mwesiamo	Village elder
Peter Mkuye	Sub-Village Chairman
Fidelis Madenge	Member
Mwambene F.V	Agricultural Extension Officer
Joseph B. Mwambinga	Sub-Village Chairman
Edigri Kihongole	Chairman
Marselina Jalala	Member
Jusutusi Kahemele	Member
Priska Mikupi	Member
Maria Mkiwa	Member
Bushiri Mfawando	Member
Udagaji Village Meeting	
Kikana kilindo	Village Chariman
Rock Kambi	VEO
Adamu Omari	Member
Jackson Msokile	Member
Salumu Kayombo	Member
A. Kilindo	Member
A. Ngaseka	Member
Hasan Ngadage	Member
Ally Kaunda	Committee Member
Aljanato Chihami	Secretary Environment
Roswita Duma	Member
Musa Kihoma	Member
Victori Msofu	Sub-Village Chairman
Shahari Hangahanga	Sub-Village Chairman
Abdala Matalasa	Member
Lugus Galusi	Member
Gwivaa Nahemi	Member
A.A Makando	Member
Stefano Kiwelo	Member
Agrino Ndembo	Member
Zamoyoni Kandila	Member
Waliyobo Mtawango	Member

Appendix 3 List of Auditors and Functional Area

Functional Area of Audit	Auditor
Vegetation	George Sangu & Kerstin Pfliegner
Social Aspects	George Sangu & Kerstin Pfliegner
Gorge Ecosystem	Kim Howell & Charles Msuya
Kihansi River Hydrology	Exaudi Fatael & Kerstin Pfliegner
Erosion, Fire Control and Waste Management	Exaudi Fatael & Kerstin Pfliegner
Health & Safety/ Institutional capacity	Kerstin Pfliegner & Exaudi Fatael
Management of the audit	Kerstin Pfliegner

Appendix 4 Checklists

Page

Checklist 1 Hydrology

1. Spatial Scope	Geographical Area to be covered	Issues to be assessed
LKHP Project Area	Kihansi River and its tributaries within the area controlled by TANESCO (1-4 km wide) around and above the dam and reservoir, downstream to its confluence with the Kilombero River	Existence, quality and use of various gauging stations
	Floodplain: Water treatment plant Tailrace canal	
LKHP works site	Hydropower infrastructure: Reservoir	Existence of Sedimentation monitoring
Organisational Scope	NEMC	
	TANESCO	
	RBWO	
	Ministry of Water and Livestock Development	
	Water User Group	Exists? Communication with RWBO and TANESCO (reports, meetings)
	LKHP Field Staff	Awareness and training on various monitoring activities, emergency preparedness/risk management, procedures to handle water quality changes
	Local Government, Agric. Extension Service	

2. Mitigation measures on the Kihansi River				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication, etc.)**	**Comments**
Bypass flow				
Is a bypass flow of 1.5-2.0 m3/s achieved on a constant basis?				
Is TANESCO monitoring the level of bypass flow? Are there reports? How often?				
Has RBWP installed automatic data loggers and staff gauges to monitor water flows and levels in the Kihansi River?				
Are they read twice daily?				
Is the data logger downloaded to a card once per week (once per month?)				
Are the staff gauges used as control gauges to calibrate the data logger?				
What are the cost involved?				
Are the cost covered by TANESCO?				
Are unusual or uncommon events such as unusually high or low flows immediately reported to RBWB and NEMC via UHV radio communication and recorded on paper at				

both the sending and receiving end?				
Is RBWB preparing an annual monitoring report that summarizes and brings together all data recorded during the previous year?				
Are copies of the report presented at the end of each year to RBWB, MWLD and NEMC and TANESCO upon request?				
Water rights				
Was the Final Water rights granted by 30th June 2004?				
Has a water user group been established for the Kihansi Catchment?				
If yes, have the RBWB reports been presented to the WUG?				

3. Mitigation measures in the LKHP Works Site				
Measure	**Yes**	**No**	**Evidence**	**Comments**
Has TANESCO commissioned any studies into alternative sources of water to substitute for the bypass flow at the Kihansi Reservoir?				
Monitoring of the Kihansi River				
Monitoring of river diversions and releases				
Hydrological and climatological data collection network continued to be operated in already established manner? (TANESCO and MoW)				
Does RBWO have sufficient information to determine the conditions to be associated with water rights and ensuring that conditions are being satisfied?				
Is the gauging station for RBWO installed 250 m downstream from the road bridge crossing the Kihansi River operational?				
Is being read regularly and data recorded? Is action being taken?				
Is the gauging station (1KB28) at the Chita-Mlimba bridge working? Is it accurate?				
Have TANESCO procedures and records been modified to conform with those of RWBO?				
Have the piezometers been integrated into the hydrological data collection? Is the status of their operation clarified?				
Do TANESCO and RBWO exchange all hydrological and hydraulic data on the Kihansi River on a real time basis?				
Is the monitoring of diversions for the Kihansi domestic water supply and spray wetlands irrigation done according to RBWO procedures?				
Have assessments of the River channel downstream of the tailrace been conducted to ascertain any erosion problems?				
Has a flow measurement station downstream of tailrace been established?				
Is there frequent reading and collection of the flow gauge records, with the use of a datalogger, by the field staff?				

Are personal observations carried out by the field staff? How often?				
Monitoring of Water Quality in the Gorge				
Is a system of water quality monitoring in place?				
Are the annual expenditures of water quality monitoring USD 30,000?				
Is it being implemented by TAWIRI and Universities as part of the RAMPO?				
Has training been conducted?				
Is sediment, turbidity, pH, BOD, COD, conductivity and biomonitoring, levels of phytoplankton being tested?				
Is the water quality monitoring including taking samples from the sprinkler system water sources, the dam, the Kihansi river water and sediments which collect in the reservoir?				
Is an annual program of soil and water quality testing being carried out? Conducted by a scientific authority? Testing arranged by several independent laboratories?				
Are records on maintenance being maintained by LKEMP personnel? (incidences of leakage, clearing of sedimentation ponds, replacement of parts) responsible for the sprinkler system?				
Is the field testing of water quality coordinated with the overall maintenance programme of the gorge?				
Any monitoring of presence of organic substances used as pesticides or fertilisers?				
Is the site staff competent to evaluate the monitoring data and empowered and authorized to respond?				
Have likely situations and appropriate responses been discussed with the site staff in advance?				
Have any other emergency preparedness measures been taken?				
Are the procedures of sudden changes in water quality being followed?				
This includes: Reporting to institutions as outlined in Annex 8 of EMP				
This includes: Sample taking as outlined in Annex 8				
This includes: Sample analysis as outlined in Annex 8				
This includes: Reporting results of analysis as outlined in Annex 8				
Is the site staff and are the implementing institutions (TAWIRI) awares of these procedures (Annex 8)?				
Monitoring of the LKHP works site (p.88)				
Is monitoring of Solid waste disposal, erosion and vegetation being executed?				
Are standard procedures for monitoring and reporting in place?				

Has the monitoring of seismic events and structural stability of the dam been included ?				
Are the expenditures for this monitoring USD 4,000 annually, carried by TANESCO?				
Seismograph and stress gauges in place and working?				
Warning system in the event of dam failure in place?				
Monitoring of sedimentation rate in the dam and release of sediments from dam during flushing operations undertaken?				
Are the cost of this monitoring annually 3,700 USD carried by TANESCO?				
Flushing plan agreed by TANESCO, RWBO and NEMC, incl. Aspects of timing, duration, total sedimentation quantities and sedimentation release rate?				
Long-term monitoring of the dam and associated installations (turbines) in plance?				

4. Institutional Capacity and Compliance check				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication, etc.)**	**Comments**
Is there a Head Engineer at site responsible for mitigation at the LKHP works site?				
Competence of Head Engineer at Kihansi responsible for mitigation at the LKHP works site?				
Who is responsible at site for mitigation at the LKHP project area? What is the competence and authority of this person?				
Is there a person responsible for monitoring at Kihansi assigned in the RBWO? What is the competence and authoritiy of this person?				
Is TANESCO responsible for operating and supervising water off-take and the release of environmental flow from the dam into the River?				
Has the final water right been granted by the RBWO by 30 June 2004?				
Is monitoring of water levels being carried out by RBWO? At which locations? How often?				
Has the water right ever been breached? Has legal action been taken?				
Is the RBWO monitoring fully financed by TANESCO? And paid via the MWLD as part of the water right?				
Is RBWO submitting a 4 monthly report to the RBWB and MWLD providing flow measurement data for various gauging stations?				
Are the regular reports being evaluated by the RBWB and a brief analysis submitted to its stakeholders?				
Is TANESCO providing on a regular and timely basis its				

data on river discharge rates and environmental flow release to RBWO? Are reports now directly to be provided to NEMC based on new EMA?				
Has RBWO at site been trained on ❑ reporting procdures (when to report emergencies, reporting formats etc.) ❑ use of radio communications for reporting ❑ procedures for responding to breaches in agreement				
Is the water monitoring financially viable? ❑ Are user fees collected from TANESCO? ❑ Is there timely transfer of funds from MWLD to RBWO for monitoring?				
As TANESCO acquired legal tenure of the project site?				
Are measures outlined in Norplan Area Management Plan regarding project site management and security; protection of project infra-structure and erosion prevention being implemented?				Head Engineer on site should have copy of this document?

Checklist 2 Occupational Health and Safety

Measure	Yes	No	Comments
1. Is there an on site health & safety representative/committee?			
2. Are there staff with 1st Aid qualifications (at least 2)?			
3. Is emergency transportation available?			
4. Presence of first Aid equipment at key locations?			
5. Is there regular training for staff on health and safety (new staff and regular updates)?			
6. Is this training for both company and contractor staff?			
7. Is information on health and safety regularly disseminated in the form of seminars, reports and brochures?			
8. Is there a running risk assessment programme?			
9. Are the staff provided with regular medical checkups?			
10. Are working hours in compliance with labour laws?			
11. Is the safety representative appointed for a term not exceeding 12 month?			
12. How many workers are in hazardous areas? Is transport readily available near by?			
13. Do each office have a first aid box? Is it well equipped?			
14. Are employees familiar with conditions of safe conduct of their work?			
15. Is there a safety policy on site?			
16. Do employees have safety rules and regulations?			
17. Is the supervisor discussing safety rules with crew (Check contents of discussion against guidelines)?			
18. Are employees, contractors and the public informed of hazards associated with corporate facilities?			
19. Maintain health of staff regular through regular medical checks?			
20. Are confidential records of all illness kept?			
21. Risk assessment to employees?			
22. Are social facilities available: club, pool, TV, communication? Other?			
23. Are employees aware of working hours 8 h/day, 40 h/week?			
24. Is risk reduction to installations and structures carried out?			
25. Do contractors submit health and safety rules?			
26. Are employees familiar with accident prevention equipment?			
27. Are health and safety rules included in tender documents?			
28. Are health and safety meetings conducted regularly between contractor and site safety officer?			
29. Do the company's field staff attend to safety seminars at least 5 times per year?			
30. Is there evidence of Safety meetings and Investigation of accidents?			
31. Is fire fighting equipment available in installations and vehicles?			
32. Are safety inspections for monitoring conducted in a 6 months interval? Are schedules there?			

33. Is there a safety audit once per year; is action taken; with making good effects within 2 months?			
34. Are accidences, diseases etc. reported to Ministry of Labour?			
35. Is there a system of equipment maintenance?			
36. Are there operating instructions, standards, formats for testing and reporting?			
37. Emergency preparedness: dam failure, tower failure, generator failure. Are drills conducted regularly?			
38. Any disciplinary actions taken?			
39. Are accidence record books kept?			

Checklist 3 Vegetation Audit

1. Spatial Scope	Geographical Area to be covered	Main issues to be assessed
LKHP Project area	Kihansi River and tributaries (Mhalala and Udagaji),	Change in flow that may cause change in vegetation patterns
	Downstream area to Kilombero confluence.	
	Wetlands created by the waterfall spray	Effectiveness of sprinklers, back up sprinklers and jet fountains sustaining vegetation
	Raphia palm groves in gorge	Temperature and Humidity levels that affect the presence of the community

2. Mitigation Measures				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication etc.)**	**Comment**
Is current flow (which is?) maintaining spray vegetation?				
Is there monitoring in the Kihansi Gorge and Udagaji gorge				
Is the vegetation monitoring undertaken at the same time each year				
Are there security checks in Gorge to prevent logging, fuel wood collection etc.				
Is there a responsible party assigned to conduct the mini catchment study				
Has the mini catchment study in Gorge been conducted				
Has the funding of US$ 30,000 for a mini catchment study been disbursed				
Have the findings been incorporated into the LWCP				
Have additional studies been conducted to assess improved use of fountain jets on vegetation				
Have studies that assess alternatives to fountain jets been conducted with regards vegetation				

3. Monitoring and Supervision				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication etc.)**	**Comment**
Has there been a land cover monitoring study that indicates changes in vegetation				
Spray vegetation: Are the 8 plots being sampled regularly (at least once a year) following Gibbs protocol				
Forest vegetation: Are the various sites being sampled annually following Gibbs protocols				
-20 plots in the Kihansi gorge				
-8 plots in the Udagaji gorge				
Has the F*ilicium* forest been affected by a reduction in humidity/ spray				
Are the indicator species present/ absent in plots; *Kupea jonii*, *Kihansi lovettii* and *Stenandrium*				

grandiflorum				
Are there epiphylls evident in riparian vegetation				
Are the woody sample plots annually monitored for change				
Are there indications of poor growth (stagnant seedlings etc?)				
Are there indications of mortality (dead stumps etc?)				
What is the cost for vegetation monitoring				
Have TAWIRI and NEMC been the responsible agencies to subcontract vegetation monitoring activities				
Has TANESCO paid the costs for recurrent activities and LKEMP a one of cost				

Record species extracted or affected.

Checklist 4 Gorge Ecosystem

1. Mitigation				
Access and control of general area (not just gorge)				
Is there control over access to the general Kihansi area, Y or N?	If Y, who is the authority? Director,	How obtained?	Any problems of people entering without permit?	Details? How is problem resolved?

2. Mitigation Measures: Sprinklers				
Working or not?	If not, how reported?			EMP
Set up correctly? Y or N				
Maintenance of sprinklers? By whom?		Names? Log book?	Where are data recorded?	
Nozzles cleaned? Y or N?	How often?	Where are data recorded?		
Nozzles replaced? Y or N?	How often	Where are data recorded? By whom?		
Pressure checked each sprinkler line? Y or N? Y	How checked?	Where are data recorded?		
Sedimentation Ponds cleaned? (dug out) Y or N?	How? Tools, shovel	How often?	Action recorded?	Manually excavated with spades at least once every 2-3 wks?
Filters in sedimentation ponds cleaned? Y or N? Y (M,J, A)	How?	How often?	Action recorded?	"even more regular basis"; if problem, what action taken?
Pipes from ponds to sprinkler systems checked for damage, etc? Y or N?	How often?	By whom?	Action recorded? booklet (M,J,A)	If problem what action taken? Maintenance (A)
Who is responsible for mitigation in Gorge and for water right?				WD
Has water right for sprinkler abstraction been obtained?Y or N?				
By whom?				WD
p.66 "for now" sprinkler to be maintained as is: what is trigger for change?				
Sprinkler support studies				
Have each of 3 sprinkler systems been tandemed with a back up? Y or N?	If Y, by whom?			
When extensive mainte-	If Y, how often is			

nance under way, are back ups used? Y or N?	extensive maintenance taking place?			
If not, what precautions are taken?				
Pipe protection				
Any done?Y or N? Yes, patrols (M,J,A)	How extensive? Patrols over whole area; (J,M,A)			
Mini catchment study, Y or N?	If Y, by whom?	Results available?	Results used in management?	This question moved to vegetation section
Sprinklers, contd				
If Y, were results incorporated in the LWide CP components?	At time of audit, LWCP had not been finalized			
Security measures to prevent poaching, logging, fuelwood collection in Gorge, Y or N? Yes, patrols (J,M,A)	Records kept of infringements? Y or N? Yes, in waterproof booklet kept in Gorge (J,M,A)	By whom? Gorge Attendants	If security, who implementing? Regular patrols? Or in reaction to violations? Regular patrols (J,M,A)	
Continued monitoring of Kihansi and Udagaji Gorge ecosystems to evaluate effectiveness of measures? Y or N?	By whom, when , how often, reports in?			Move to Vegetation section
Water right application submitted for mitigation actions? Y or N?	By whom? Wildlife Division			"the agency ultimately responsible for mitigation". See footnote 17 p 71, am not sure why it is repeated
p.67 implementing agencies				
Who has done these things?				WD and subcontracting local teams, company or agency, "implementation of vulnerability reduction program)
Studies for LWCP and reduce vulnerability to piping system, Y or N? (M)				

3. Mitigation Measures Fountain Jets				
				EMP
Maintenance, Y or N? Yes	What? Sometimes	By whom? Gorge	Cost?	$5,000 for

(M,J,A)	clogged, so un-clogged	Attendants(J,M,A)		spares, etc
Any further trials, varying variables, jets, aim, etc? Y or N? N (M) but we are told they are in the pipeline, to take place in September	If Y, by whom? Norplan to add tandem sprinklers and to examine issues related to fountan jets	When? Sept 2005	Report? Work not done yet	Further trials varying size of jets, change of angles, etc
Any study of alternative to f. jets? Y or N? N (M)	If Y, by whom? See above, presumably Norplan	When?	Report?	$30,000
Expansion of f. jets? Y or N	See above, presumably Norplan			Expansion …offers perhaps best opportunity for provision of some mitigation in adjacent wetlands
Any money spent?				5 thou for maintenance
Paid to whom?				
When?				
Who funding? Annual maintenance				TANESCO for annual recurrent costs
Study				LKEMP
Has study been done?				Given as one off to be begun in 2004

Note: Jets installed Dec 2001, some erosion problems so now aimed at river channel instead of Upper Spray Wetland where they caused erosion and removal of vegetation.

5. Mitigation Meansures, Ex situ captive breeding programme			
Has it begun?Y or N?	If Y, by whom? Complex operation, WD, many other actors	When? Dec 2000 (check date)	
p.69 What are the actual costs of the captive breeding programs to the zoos?	If not known, why not?	What needs to be done to provide this info?	
Ref is made to "expensive and burdensome" costs in Captive Breeding Agreement: What are these?	M not aware		
Has govt reviewed contract? Y or N?	If Y, details: when? Findings? Any action taken		
An open question: Follow up: contract is signed by 2 parties: what do other stakeholders think?			
Has additional funding been made available to ensure continuation of pro-	If so, what are implications?	Players? IAP's?	

gramme?Y or N	When will be available? How implemented?		
TAWIRI is listed (p.69) as body which will deal with initiation of CB programme in Tz. Has this happened? Y or N?			
Annual reports of CB program available? Y or N?	If so, produced by whom?		
Has the CB program been reviewed on an annual basis? Y or N	If Yes, by whom?	Any implications, changes, financial implications?	NEMC to review annually on basis of annual reports
How much money spent in Tz on CB?			$75,000
How long will it go on?			Continuous and indefinite, subject to annual review

6. Mitigation Measures: Upkeeping of Gorge Ecosystem			
Structures maintained? Y or N? Y (M, J,A)	If Y, by whom? Gorge attendants How frequently? Daily Any oversight, monitoring? Daily inspection	Record keeping?Yes, recorded in waterproof book	Maintenance team of the Research Station facility that will be made by LKEMP in 2004.
Costs?			
Payment?	Source? LKEMP	How?	
Off-site infrastructure, storage facilities for spares, monitoring equipment: present Y or N? Y (M, J)			
Maintenance team infrastruacture, indoor work area, office, housing: present, Y or N? Yes			
UHF radio network: present, Y or N? Y (M,J,A)			
Vehicle, present, Y or N? Y (M, J,A)			
Funds expended?			$28000 budget

Note: Bridges, walkways, ladders, small shelter, “any other facility” required/installed in future
By 6 local staff members, 1 team leader

7. Mitigation: Restriction and Access to the Kihansi Gorge Wetlands				
				EMS
Is access restricted to Gorge wetlands ? Y or N? Y (M, J,A)	If Y, how? Authority? DG LKEMP	By whom? DG LKEMP	Cost? No physical barrier but usually visitors	WD, no clear budget line, lumped with infrastructure

			are accompanied by Gorge Attendent (s)	
Safety Protocols				
Who sets up?LKEMP	Who enforces? LKEMP			WD
Any revision, changes, modifications? Y or N?	If Y, what system is in force? If No, why not?	Knowledge feedback?		
Who releases funds? LKEMP				TANESCO
For how long?	Length of project?			indefinite

8. Mitigation: KST studies				
				EMP
Have any studies been conducted? Y or N?				
Are safety protocols enforced (p.70) Y or N? Y (M,J,A)				
Other studies suggested in EMP regarding ecosystem/KSTs				
Study on maximising habitat, spraying toad rock, etc? Y or N?	If Y, by Whom?	Dates?	UDSM and foreign University	
Studies of General diurnal behaviour studies, predation, reproduction, etc, Y or N?	If Y, by whom?	Dates?		
Longevity, Y or N?	If Y, by whom? Report available?	Dates? Report used?		
Food preferences, Y or N?	If Y, by whom? Report available?	Dates, Report used?		
Pathogens of KST, chytrids, Y or N? N(M) but see caveat	If Y, by whom? Report available?	Dates, Report used?		
Funds made available for competitive research grants, Y or N?	If yes, how much?			
NEMC indicated preferences, Y or N?	If yes, which ones?			
NEMC chose proposals, etc., Y or N?	If yes, which ones and value?			
Funds used by LKEMP in 2004, Y or N?	If Y, which studies funded? How much?	If N, why not?		
Value of studies funded?				
Timing?				

9. Monitoring: Kihansi Spray Toad pg. 83				
Counts				EMP
Do Kihansi Spray Toad counts conform to Vol III IREM report? Y or N?	Generally Yes but see exceptions based on interviews			

	Daytime permanent rock plots Y or N?			
	Plots along vegetation Y or N?			
	Use of standard recording sheet Y or N?			
	Counts in spray wetland Y or N?			
		.5mx.5m quadrats along transects		
		Spray wetland vegetation, Lower, mid Gorge and main falls wetlands.		5 times if popns recover
		Upper Gorge wetlands		
		Lower Gorge wetlands		
		Mid Gorge wetlands		
		Main falls wetlands		
Temp and Humidity Y or N?		Note: KMH saw data on computer in office had been downloaded in excel		
	Has it been continued? Y or n?	According to LEMP methods ?		
	Has additional intensive monitoring of spray input in the upper wetland ecosystem been effected? Y or N	If Y, by whom?	Is report available? Y or N? Where?	
			Have data been used by decision makers? Y or N?	
p.83 Kihansi AND Udagaji forests using LEMP methods and protocol by Gibbs?Y or N	If Y, how often, by whom, etc	Documentation? Where?		This question belongs in vegetation section

p.85 Table 6.1 Habitat Monitoring Activities				
Precipitation monitored daily in mm, Y or N?	Confirm gauge(s) present	Data sheets, or logger?	Reported how? To Whom? How often?	
Air Temp deg C recorded daily, Yor N?	Confirm gauge(s) present	Data sheets, or logger?		
Wind speed in km/hr monitored at 1 site daily, Y or N?	Confirm gauge(s) present	Data sheets, or logger?	Reported how? To Whom? How often?	
Relative Humidity in % monitored daily, 1 site, Y or N?	Confirm gauge(s) present	Data sheets, or logger?	Reported how? To Whom? How often?	
Sprinkler System Flows (liters/s) continuously monitored, Y or N?	Confirm gauge (s) present	Data sheets, or logger?	Reported how? To Whom? How often?	
Sprinkler System Water Temp deg C monitored, Y or N?	Confirm gauge(s) present	Data sheets, or logger?	Reported how? To Whom? How often?	
Sprinkler System Water pH monitored, Y or N?	Confirm gauge(s) present	Data sheets, or logger? Data sheets	Reported how? To Whom? How often?	
Soil moisture in mbars (10/wetland) measured daily, Y or N?	Confirm gauges working	Data sheets?	Reported how? To Whom? How often?	
Erosion deposition around soil cracks in mm/month, 25/wetland, measured monthly, Y or N?	Confirm visually	Data sheets?	Reported how? To Whom? How often?	
Suspended solids/sediment/turbidity of applied sprinkler system water, 2 sites, monitored daily/continuous Y or N?	Confirm methods	Data sheets?	Reported how? To Whom? How often?	
Droplet density, size, recorded at 1 site, monthly, Y or	Confirm methods	Data sheets?	Reported how? To Whom? How often?	
Kihansi Spray Toad Surveys, using IREM and Panel of Expert Monitoring techniques, 2-5 times/year, Y or N?		Reports seen? Yes	Reported how? To Whom? How often?	
p.86 Frequency & Responsibility of Habitat Monitoring				
Is Gorge Ecosystem being managed by WD (who are also to manage mitigation measures)? Y or N?	Evidence of this in form of name of person, etc?	Documentation as regards management by WD?		
Is TAWIRI carrying out the monitoring?	If Yes, is a RAMPO* based permanently at	Documentation available?		*Research and Monitor-

	Kihansi to manage and coordinate monitoring program?			ing Programme Officer
	Has TAWIRI contracted or subcontracted chytrid specialist?	If Yes, who, timing, etc?	Report available?	
Is WD (or its contractor) continuously monitoring the sprinkler mitigation system? Y or	If yes, records, details available? Y or N	Copies seen?		
Is annual monitoring of wetlands towards end of dry season using protocols devised by IREM and elaborated by Gibbs (2004) being conducted, Y or N?	If yes, records, details available?	Copies seen?		
Are Kihansi and Udagaji forests receiving continued monitoring using protocols devised by LEMP and described by Gibbs (2004)?Y or N?	To go to vegetation section			
Has annual re-measuring of the permanent sample plots established under LEMP taken place towards end of the dry season? Y or N?	To go to vegetation section			
Has monitoring, etc as listed in Table 6 using LEMP and IREM protocols takenplace? Y or N?				
Has Bi-annual measurement in hot (jan0Feb) and cold (Jul-Sep) seasons taken place to complement previous measurements?				

10. Vertebrates in particular amphibians					
No.	page			Comments	Related to:
1	exec summary	Land, control, institutional	Does Tanesco have title deed?	Must there be a cadastral survey to get title deed in Tz?	Land policy, village land, forests, local management of area
2	Es	Water, institutional	Has Wildlife Division the water right for sprinklers?		Does this include water for jet spray?
3	Es	Institutional control	Does NEMC have trained, dedicated staff to manage	How assess? Cvs?	
4		Institutional control	Does Tanesco have trained, etc staff?	As above	
5	?	Is there control to enter area?	Request to see log books of all visitors; tanesco workers, scientists, locals?	This is not just a security issue but may be related to chytrids	
6	24	There seems to be little	Basic fault in eia and	Check WB criteria	Also Tz water

		interest in the ecosystem integrity of below dam river	project?	and policy as regards need to maintain integrity	policy, etc.
7	26	No crocs noted, bridge?	Anecdotal reports of 2 deaths there 1994, etc.		
8	?				
9	62	Bypass flow; institutional, control, monitoring	Claimed given on a “regular basis”	Records? Discrepancies?	See Mkhandi report, Dec 2003
10		Captive breeding	No data presented	How do stakeholders, etc obtain information?	Many other issues:
11	32	Local govt implementation (general comment)	Any regular reporting? Copies of reports?	Reporting to whom? Central govt agencies?	A general comment
12	34	How will new legislation be flagged in subsequent versons of emps? l	Covered, see annex 4		
13	36	Cross sectoral	Min. of Energy is missing, table 2.3		
14	37	Institutional	How do we assess if tawiri, wd, etc are working?	Fbd officer based in mlimba;	
15	38	Emp targets	Says wd needs support to see that these are met	Have they been met after one year?	
16	39	NEMC to befunded by tanesco			
17	40	Keeps mentioning LWCP (landscape wide cons plan)			
	69	Unusual event reporting, water	Have there been any? Do we have written reports?		

Checklist 5 Natural Resource Audit

1. Spatial Scope	Geographical Area to be covered	Main issues to be assessed
LKEMP Project Area	Kihansi River basin upstream of LKHP specifically 2 villages from Mufindi Uhafiwa and Ukami villages.	Activities promoting proper land use and environmental conservation are being implemented
LWCP	LKEMP project area i.e., the Kihansi basin upstream of LKHP	Inclusion in LWCP
	Farmland and forest between the restricted area	
	Njerera Forest reserve and Udzungwa escarpment forest Reserve areas adjacent/ traversing project	
LKHP works site	The miombo woodland along the escarpment and other areas cleared by LKHP that are to be rehabilitated	
Organisational Scope	NEMC	
	TANESCO	
	LKEMP	
	DoE	
	Ministry of Water and Livestock development	
	AgES	
	Land Office	

2. Mitigation measures from the EMP				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication etc.)**	**Comment**
Natural Resource management				
Does the LWCP include continuation of CMP activities on proper land use practises and environmental conservation				
Has LKEMP financed natural resource programmes in the catchment in 2004				
Have the EAMCEF been contacted for funding of natural resource management programmes				
Do local government have funds or sources for natural resource management programmes				
Have the ministry of Water and livestock development been contacted as funding source for natural resource programmes				
Has ministry been involved in preparation of the LWCP				
Has the estimated cost of 150,000USD been revised in the final LWCP				
Is there encroachment in the Njerera Forest Reserve				
Is there encroachment on the Udzungwa escarpment forest boundary				
Are there incentive programmes for sustainable land use				
Is there a penalty for improper practise				
Does the LWCP include a programme advocating cultivation of crops that do not require irrigation				
Does the LWCP include a community forestry programme				

Is monitoring of existing abstraction included in the LWCP				
Have the implementing agencies been involved in preparation of the LWCP i.e., Local government, AgES, RWBO and TANESCO				
Does the LWCP stipulate that the costs for water abstraction management programme to be included in the water rights payment				
Awareness and Enforcement				
Does the LWCP include awareness and extension programmes to ensure compliance to existing legislation for natural resource management				
LKHP work site				
Is the *Miombo woodland* on the escarpment adequately vegetated (road to dam site) to prevent erosion				
Are re-vegetated areas in the LKHP works site maintained?				

3. CMP objectives				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication etc.)**	**Comment**
Is land pressure significant in catchment?				
Are there water user groups?				
Are there fires in the catchment?				
Is erosion a problem in the catchment				
Are there control measures for deforestation?				
Are there public awareness programmes for compliance with national legislation?				
Has there been monitoring for changes in land cover				
Do Uhafiwa and Ukami have village PRAs which include issues of natural resource management				
Are these activities being implemented				
Is there continued regular training of farmers				
Do villages have paraprofessionals				
Are paraprofessionals regularly trained				
Do villages have access to district extension staff				
Are district extension staff regularly trained				
Are the village based environmental committees active				
Do they receive financial and or technical support				
Are the grass root voluntary groups active				
Do they receive financial and or technical support				
Are awareness campaigns continued in communities close to reservoir				
Do farmers receive access to soil conservation and afforestation material (seeds etc.)				
Do farmers receive technical support on improved tree planting				
Are there established monitoring protocols for farming methods				
Are there established monitoring protocols for livestock movement				
Was there a smooth transfer of responsibility from CMP to local government				

Checklist 6 Socio – Economic Aspects

1. Spatial Scope	**Geographical Area to be covered**	**Main issues to be assessed**
LKHP	LKHP works site (Staff)	
	Villages on lowland, Mlimba, Udagaji and Kalen-gakelu. Villages in Catchment; Ukami and Uhafiwa	
LWCP	Kihansi Catchment (For this audit only Uhafiwa and Ukami areas)	
Organisational Scope	Ministry of Health	
	Local government authorities (Mufindi and Kilombero Districts)	
	NEMC	
	TANESCO	

2. Mitigation measures from EMP				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written commu-nication etc.)**	**Comment**
LKHP staff				
Is there a responsible party for environmental issues at LKHP				
Is there an environmental and socio-economic mitigation plan of action for LKHP works site				
Are consequences of natural resource extraction being addressed				
Is there provision for socio-economic manage-ment in coordination with local residents on for-est resource exploitation				
Has TANESCO established a cost centre to fund forest related activities				
Do the environmental mitigation activities spend 6000USD at LKHP site				
Is 4000USD spent on socio-economic mitiga-tion				
Health				
Has the local Government taken over the activi-ties run earlier by MUAJAKI on human health				
Has the multi-sectoral committee through LKEMP actively examined opportunities for continuance of MUAJAKI and SEMA-Ki ac-tivities				
Has there been an evaluation of the effective-ness of MUAJAKI and SEMA-Ki programmes				
Does the LWCP include programmes of; defor-estation; water abstraction, encroachment into marginal lands and fire incidence.				
Has the LWCP budgeted 30,000USD a year for				

activities in Human health mitigation				
Have the local governments been included in the preparation of the LWCP of which they are to implement				
Is the source of funding for the LWCP human health programme Local government				
Employment and local communities				
Does TANESCO uphold a local's first policy when employing				

3. Monitoring measures from EMP				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication etc.)**	**Comment**
Monitoring in the Catchment				
Does the LWCP include development of a baseline study to monitor land cover/ land use changes using satellite imagery or aerial photography?				
Does this study include ground truthing by means of a socio economic study to assess reasons for changes				
Does the LWCP stipulate 50,000USD funding for the baseline to be re-mapped every 4-5 years				
Does LKEMP have the funding for this activity				

4. MUAJAKI sustainability			
Spatial Scope	Geographical Area to be covered	Main issues to be assessed	Possible evidence to be collected
LKHP Project area	18 villages surrounding LKHP and site personnel For purposes of the audit this is limited to Mlimba, Udagaji, Kalengakelu, Ukami and Uhafiwa	What happened after the closure/ pull out of the donor funded programme	Opinions on effectiveness/ weaknesses of the programme. Information on programmes that are currently on-going emulating or continuing the activities of MUAJAKI

4. MUAJAKI mitigation during operation of LKHP				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication, etc)**	**Comment**
Is there a Kihansi Management Committee				
Do the districts have financing and capacity to conduct programmes initiated by MUAJAKI				
Upland Malaria				
Is there health education available for local communities and individuals on malaria				
Are bed nets available				

Is there support to malaria case management in local clinics				
Is there monitoring of vector habit				
Is there monitoring of malaria transmission				
Is there monitoring of malaria transmission				
Is there monitoring of malaria morbidity				
Is there monitoring of malaria mortality				
STDS/HIV				
Is there health education provided for local communities and individuals on STDs/HIV				
Are condoms marketed				
Is there technical and material support to STD clinics				
Do the clinics provide Voluntary counselling and testing services for HIV				
Is there material being distributed on health/ behaviour change in the communities				
Have local and district assistants been trained after the project				
Are there any clinics (health centres and dispensaries) that have been rehabilitated post construction				
Has cost sharing been introduced in local clinics?				
Are there regular inventories of units and equipment				
Is Maternal and Child health information disseminated to TBAs and Local clinics				
Is there regular monitoring of the STD/HIV and malaria programmes at household level				

5. SEMA-Ki sustainability			
Spatial Scope	**Geographical Area to be covered**	**Main issues to be assessed**	**Possible evidence to be collected**
LKHP Project area	8 villages closest to LKHP two in Mufindi district (Ukami and Uhafiwa) and six in Kilombero district (Udagaji, Chisano, Mgugwe, Kalengakelu, Mwembeni, Mlimba-A and B) For the audit this is limited to Mlimba, Kalengakelu, Udagaji, Ukami and Uhafiwa	What happened after the closure/ pull out of the donor funded programme	Opinions on effectiveness/ weaknesses of the programme. Information on programmes that are currently on-going emulating or continuing the activities of SEMA-Ki

6. SEMA-Ki mitigation during operation of LKHP				
Measure	**Yes**	**No**	**Evidence (Report, stated fact – by whom? Written communication, etc)**	**Comment**
Is there a Kihansi Management Committee				
Do the districts have financing and capacity to conduct programmes initiated by SEMA-Ki				
What the financial resources allocated for these activities				

Are there funding agencies involved with these activities				
Are there adequate health facilities				
Are there adequate market facilities				
Is water for domestic use a problem				
Is there knowledge and skills that allow exploitation of natural resources in a sustainable manner				
Are locals being provided with know how for economic improvement				
Are communities sensisitised on how to handle influx populations				
Is there continuance in village government training on sustainable development for communities				
Have initiated social amenities infrastructure been completed				
Are there additional social amenities infrastructure constructed post SEMA-Ki				
Are environmental committees functional/ active				
Are there environmental additional committees initiated				
Do the communities receive regular training for tree seed nursery care				
Are nurseries still active				
Are there active micro finance groups in communities				
Do marginalised groups have access to financing				
Are there workshops held for capacity enhancement in the community				
Do the communities have a platform to generate recommendations for mitigation to LKHP				
Is the mediation of disputes and misunderstandings between LKHP and the communities effective				
Is there small scale development related assistance provided to the communities				
Is there regular sensitisation on impacts that arise from population increments				
Is there periodic monitoring of changes in local amenities				
Are there youth and women groups involved in economic activities				

Appendix 5 Itinerary of on-site audit

<table>
<tr><th>Audit</th><th>Auditor</th><th>Day 1 (Thursday)</th><th>Day 2 (Friday)</th><th>Day 3 (Saturday)</th><th>Day 4 (Sunday)</th></tr>
<tr><td>Vegetation</td><td>George Sangu</td><td rowspan="6">- Site walk/drive

- Check locations & stations

- Staff meeting</td><td rowspan="2">Gorge</td><td rowspan="2">Cachments & upstream villages</td><td rowspan="2">Downstream villages/ Turbines/ Water treatment plant/ Debriefing</td></tr>
<tr><td>Social</td><td>George Sangu & Maj Forum</td></tr>
<tr><td>Ecosystem</td><td>Kim Howell & Charles Msuya</td><td colspan="2">Gorge Ecosystem & Sprinklers</td><td>Turbines/ Water treatment plant/ Debriefing</td></tr>
<tr><td>Hydrology</td><td>Exaudi Fatael</td><td>Dam site & top of Gorge</td><td>River</td><td></td></tr>
<tr><td>Health & Safety/ Institutional capacity</td><td>Kerstin Pfliegner & Exaudi Fatael</td><td></td><td></td><td>Work site/ Dumpsite/ Health clinic/ Turbines/ Water treatment plant Debriefing</td></tr>
<tr><td>Management of the audit</td><td>Kerstin Pfliegner</td><td>Gorge</td><td>Cachments & upstream villages</td><td></td></tr>
</table>

Appendix 6 Implementation of IREM Recommendations

IREM Recommendation	Assessment
Maintain a continuous minimum bypass flow from the LKHP dam of at least 1.5 m^3/s at all times. An independent monitoring mechanism should be established to ensure that the continuous minimum bypass flow is adhered to at all times and that no interruptions occur.	Minimum bypass not maintained as established through independent monitoring. Bypass is presently being increased, date 4. October (meeting with RAMPO).
Maintain and possibly extend the artificial spray systems and other infrastructure currently in the Kihansi Gorge. An appropriate institution (e.g an NGO with appropriate experience in biodiversity conservation) needs to be identified and funded to take responsibility for the operation and maintenance of the artificial spray systems. An independent monitoring mechanism should be established to ensure that the spray systems are successfully and continuously operated and maintained.	TAWIRI, through secondment of RAMPO, in charge of maintaining spray systems. Extension has to date not been investigated. Independent monitoring mechanism not been established. This audit possible initial step of such monitoring system.
Continue monitoring of the Kihansi Spray Toad, the spray wetland ecosystem and the Kihansi Gorge. It is not considered necessary to maintain the same intensity of monitoring inside the spray wetlands as during 2001.	Recommendation followed.
Intermittent high flows not to be studied further at this time, although this is under the assumption that the spray systems are properly operated and the continuous bypass flow is maintained	Recommendation followed. In 2005 no population of Spray Toads was found in the Gorge. Hence it is not possible to discuss the need for long-term testing of flow regimes.
Further studies to be carried out on the Upper and Lower Lufulutonya Spray Wetlands (upstream of the LKHP dam) and the Udagaji Gorge Spray Wetlands as a basis for making a future decision on whether translocation should be pursued.	Studies not conducted.
Searches focusing only on the spray toad not to be continued, since the likelihood of finding the same species at another site is now very small. Instead it is recommended that expertise on biodiversity value be concentrated on areas threatened by other infrastructure development, and as mentioned below.	Searches on toad were discontinued.
Captive breeding to be continued and that study resources be put into carrying out research on this population in close co-operation with the in situ studies.	Captive breeding is being continued. Studies lack behind.
IRA recommend a complex institutional structure for conservation of 5 different units within the Kihansi Gorge Conservation Area, while NORPLAN recommend a simpler uniform conservation status be immediately established for the entire area, while lengthy legal processes are developed for establishing a Nature Reserve in the immediate Gorge zone	Simplified institutional set up does not seem to have been established. Current set up still complex.
A review to be carried out of the environmental-decision making process associated with LKHP such that the important lessons learned here will assist future projects with similar problematic issues to face.	Has not been done.

Appendix 7 Results of the Captive Breeding Programme

Report number	Date	Which of 3 annual reports for the year?	Total number of living ex situ Toads in	Notes
1				Not available
2				Not available
3	8 April 02	1/3	74 Adult, 278F1, 5 F2= 357	Report notes that it is not possible to use a studbook system to manage the populations; WCS requests a renewal and renegotiation for permission to use any and all standard management techniques to manage the toads. Fort Worth Zoo, Dallas Texas and Buffalo Zoo, Buffalo, New York have requested to participate in the programme.
4	14 July 02	2/3	58Wild, 330F1, 192F2=580	Increased misting cycles spurred heavy vocalizations and amplexus in wild and F1 toads at WCS. Visit by Dr. M. Ngoile, E. Severre, and Dr. W. Sarunday expected in Aug 2002.
5	6 Dec 02	3/3	49Wild, 192F1, 186F2=427	WCS animals continue to produce F2 progeny. Other zoos experienced some problems due to heat stress and other medical issues.
6	4 April 03	1/3	37Wild, 135F1, 97F2, 1F3=270	First F3 born in WCS; WCS ships some to Oklahoma and Baltimore Zoos
7	25 July 03	2/3	35Wild, 106F1, 94F2, 1F3=236	Oklahoma has only 2 F1 toads; Toledo Zoo shipment were delayed in flight and only 8/12 survived. Due to slow permit process, neither Forth Worth nor Buffalo zoos have received toads since official requests made in Sept 2001!
8	10 Dec 03	2/3	Total of 93*	Numbers generally dropping; none at Oklahoma. Some shipped to Buffalo, but none to Fort Worth because numbers at WCS critically low. WCS animals suffering “short tongue syndrome” and rear limb paralysis
9	16 March 03	1/3	Total of 71*	Due to drop in numbers, efforts consolidated at Toledo and Bronx (WCS) zoos. Mortality has levelled off as a whole; support sought from WB and LKEMP for captive propagation program.
10	10 July 04	2/3	Total of 82*	Toads breeding, juveniles growing;
11	22 Sept 04	3/3	102*	Permission obtained from Tanzania to establish a living cell line. WCS still awaiting news regarding establishment of a captive breeding fund for KST. Premature toads born at Toledo Zoo.
12	8 March 05	1/3	96*	No more toads have been bred. New equipment installed may change this. Tissue line establishment attempted but not successful. Zoos awaiting news on renewed MOU, captive breeding fund, and permission on disposition of biomaterials for future research.

*= because animals have mixed between generations, individual identities and generation no longer identifiable for discrete census calculations.

Appendix 8 Training and Other Support Provided

SECTOR	ACTIVITY/SUPPORT PROVIDED
1.Energy Sector	**MEM** • Sponsored 2 employees in MSc.(Paul Kiwele & Hamad Masauni Yusuf) • Donated various equipments: 1Laptops, 1PC, 1Printer, & 1UPS • Supported various short term staff training to strengthen the MEM Environmental Unit **TANESCO** • Supported Hydrological modelling activities • Supported EMP implementation & mitigation measures • Donated Various equipments (2 Laptops, Telemetry, & GIS Mike 11 Arc view) • Supported various short term staff training to strengthen the Environmental Unit • Supported the preparation of the Updated Environmental Management Plan
2.Water Sector	**MWLD** • Donated one Laptop **RBWO** • Donated one Motor Vehicle, Toyota Land cruiser Hard Top • Donated various equipments PC, Laptop, Printer, UPS & Data loggers • Donated one Motorcycle, Suzuki to facilitate hydrological monitoring in areas inaccessible by motor vehicles • Prepared and supported the implementation of the RBWO hydrological monitoring program • Sponsored attendance to international conference
3.University of Dar es Salaam (Academia)	**ZOOLOGY** • Donated one Motor Vehicle, Toyota Land cruiser Hard Top • Sponsored 2 UDSM staff for MSc in Environment. (Hashim Mangosongo & Catherine Masao) • Sponsored 2 UDSM staff for PhD in Conservation Biology. (Flora Magige & Radhia Ideva) • Recruited one Lecturer in Conservation Biology, October, 2004. (Francis Muthuri) • Procured and donated various IT equipments and materials to support the teaching of Conservation Biology in the University **WATER RESOURCES MANAGEMENT** • Sponsored 2 UDSM staff for MSc in Water Resources Management. November, 2004. (Joseph Ochieng & Bahati Joyce) • Sponsored 4 students to MSc in Water Resources Management. April, 2005. (Martha Kamuzora, Upendo Eliuze, Mwita Matiko, & Richard Wilfred) • Recruited an External Lecturer in Water Resources Management (Prof. Kachroo) • Procured and donated various IT equipments and materials to support the teaching of WRM
(Environmental Sector)	• Financed Drafting the Environmental Law (EMA, 2004) • Financed the drafting of EIA regulations and guidelines • Sponsored one staff for MSc in Environmental & Resources Management. December, 2004 (Onespholy Kamukuru) • Donated various equipments: 3 Laptops, 1Printer, & 1UPS **NEMC** • Donated one Motor Vehicle, Toyota Landcruiser Station Wagon • Donated various equipments: 2 Laptops, 1PC, 1Printer, surge arrester, & UPS • Sponsored various short courses and international conferences • Supported establishment of NEMC Website (nemctan.org)
	• Supported the preparation of the detailed ecological monitoring protocols for the Kihansi Gorge
	• Supported the preparation of the Landscape-Wide Conservation Plan for the Kihansi river upstream catchment areas

5.Wildlife Sector	**TAWIRI** • Sponsored attendance to international conferences • Sponsored training of one Employee for MSc in Wildlife Management - September, 2004 (Edward Kohi)
6. Districts & Communities	• About 100 million Tanzanian shillings set aside to implement environmental management sub-project formulated by district councils and local communities in the catchment areas upstream the Kihansi River for FY 2005/06 • Implementation of the capacity building program for districts (Kilolo, Kilombero & Mufindi) and communities is underway. Already the Financial & Procurement procedures and sub-project preparation manual for the District and Community grant scheme are in place.

Long Term Professional Training - PhD Scholarship						
S/No.	**Course Title**	**Venue**	**Dates**	**Duration**	**Institution**	**Individual Beneficiaries**
1.	PhD in Conservation Biology (**Limnology**)	University of Vienna Austria	2003 – 2006	4 Years	University of Dar es Salaam	Radhia Ideva
2.	PhD in Conservation Biology (**Ornithology**)	Norwegian University of Science and Technology Norway	2003 – 2006	4 Years	University of Dar es Salaam	Flora Magige
Long Term Professional Training – M.Sc. Scholarships						
S/No.	**Course Title**	**Venue**	**Dates**	**Duration**	**Institution**	**Individual Beneficiaries**
1.	MSc. of Environment and Energy Management	University of Twente, Cartesius Institute at Netherlands	Feb. 2003 – Jan. 2004	1 Year	Ministry of Energy and Minerals	Mr. Paul Morris Kiwele
2.	MSc. in Conservation Biology	University of Kent at Canterbury, UK	22nd Sept. 2003 – Sept. 2004	1 Year	University of Dar es Salaam	Mr. Hashim Mangosongo
3.	MSc. in Conservation Biology	University of Kent at Canterbury, UK	22nd Sept. 2003 – Sept. 2004	1 Year	University of Dar es Salaam	Ms. Catherine Masao
4.	MSc. Energy Environmental Technology and Economics	City University of London	Jan. 2004	1 Year	Ministry of Energy and Minerals	Mr. Hamad Masauni Yusuph
5.	Masters Degree in Environment and Resources Management	Brandenburgisc Techrische University tat Coltbus Germany	Oct. 2004 – Sept. 2006	2 Years	Division of Environment, Vice President's Office	Mr. Onespholy M. Kamukuru
6.	Msc. In Wildlife Management and Conservation	Wageningen University The Netherlands	Sept. 2004 – August, 2006	2 Years	TAWIRI	Mr. Edward M. Kohi
7.	Masters Degree in Watershed Management/Modelling	University of Dar es Salaam	Oct. 2004 – Nov. 2006	2 Years	University of Dar es Salaam	Mr. Mwita Matiko
8.	Masters Degree in Watershed Management/Modelling	University of Dar es Salaam	Oct. 2004 – Nov. 2006	2 Years	University of Dar es Salaam	Ms. Martha Kamuzora
9.	Masters Degree in Integrated Water Resource Management	University of Dar es Salaam	Oct. 2004 – Nov. 2006	2 Years	University of Dar es Salaam	Mr. Richard Wilfred
10.	Masters Degree in Integrated Water Resource Management	University of Dar es Salaam	Oct. 2004 – Nov. 2006	2 Years	University of Dar es Salaam	Ms. Upendo Eliuze
Short Term skills development training courses including support to attend Workshops, professional seminars and conferences						

S/No.	Course Title	Venue	Dates	Duration	Institution	Individual Beneficiaries
1.	Procurement of Consultancy Services	Ghana Institute of Management and Public Administration	1st – 19th July – 22nd – 25th July, 2002	4 Week	LKEMP	Dr. Wilfred N. Sarunday
2.	Hydrovision 2002 Conference	Portland, Oregon in the US	July 28 – Aug. 2, 2002	1 Week	TANESCO	Mr. Kamugenyi. Luteganya
3.	Hydropower and Environment	International Centre for Hydropower (ICH), Trondheim Norway	Aug. 24 – Sept. 13, 2002	4 Week	TANESCO	Mr. Hamdun R. Mansur
4.	Environmental Impact Assessment	Stockholm and Gothenburg, Sweden	May 5 – June 6, 2003	4 Weeks	NEMC	Mr. Kassim Sengoe
5.	IUCN World Parks Congress V(WPC)	Durban, South Africa	Sept. 8 – 18, 2003	2 Weeks	NEMC	Dr. M.A.K. Ngoile
6.	Management and Leadership Skills for Optimal Performance	Kilimanjaro International INC, USA	18th – 29th August, 2003	2 Weeks	LKEMP	Dr. Wilfred N. Sarunday
7.	Procurement of Consultancy Services	Ghana Institute of Management and Public Administration	27th – 30th October, 2003	1 Week	LKEMP	Mr. Shushuu J. Maguya
8.	System Administrator	University of Dar es Salaam Computing Centre	22nd Sept. – 14th Nov. 2003	3 Months	LKEMP	Ms. Lillian Somi
9.	Procurement and Stock Control	Awesome School of Information Technology	13th Jan. – 24th Jan. 2004	2 Weeks	VPO	Ms. Kisa Mwantobe
10.	Procurement and Stock Control	Awesome School of Information Technology	13th Jan. – 24th Jan. 2004	2 Weeks	NEMC	Mr. Sadik Sangawe
11.	Procurement and Stock Control	Awesome School of Information Technology	13th Jan. – 24th Jan. 2004	2 Weeks	LKEMP	Ms. Bahati Jasson
12.	Global Spatial Data Infrastructure (GSDI-7)	India	Jan. – Feb. 2004	1 Week	NEMC	Mr. Vedast Makota
13.	Convention on Biological Diversity	Kuala Lumpur	Feb. 9 – 27, 2004	3 Weeks	VPO	Ms. Mary Mushi
14.	Convention on Biological Diversity	Kuala Lumpur	Feb. 9 – 27, 2004	3 Weeks	VPO	Prof. Yadon Kohi
15.	Convention on Biological Diver-	Kuala Lumpur	Feb. 9 – 27, 2004	3 Weeks	VPO	Mr. Eric Mugurusi

	sity					
16.	Financial Management, Disbursement and Procurement	Zanzibar Beach Resort Hotel	April 14 – 16th, 2004	3 days	LKEMP	Dr. Wilfred N. Sarunday
17.	Financial Management, Disbursement and Procurement	Zanzibar Beach Resort Hotel	April 14 – 16th, 2004	3 days	LKEMP	Mr. Harold Materu
18.	Financial Management, Disbursement and Procurement	Zanzibar Beach Resort Hotel	April 14 – 16th, 2004	3 days	LKEMP	Mr. Shushuu J. Maguya
19.	Financial Management and Disbursement	Malawi Institute of Management	April 26 – May 7, 2004	2 Weeks	LKEMP	Dr. Wilfred N. Sarunday
20.	Financial Management and Disbursement	Malawi Institute of Management	April 26 – May 7, 2004	2 Weeks	LKEMP	Mr. Harold J. Materu
21.	Environmental Impact Assessment	Sweden	May 17 – June 18, 2004	4 Weeks	NEMC	Mr. Godlove Mwamsojo
22.	Water Resources Management, Data Processing and Analysis	Institute foe Meteorological Training and Research, Nairobi – Kenya	6th Sept. – 3rd Dec. 2004	4 Months	TANESCO	Ms. Joyce Nzali
23.	Study Tour on EMS formulation and implementation procedures	ZESCO – Zambia and ESKOM – South Africa	Sept. 2004	10 days	TANESCO	Mr. David Ngula
24.	Study Tour on EMS formulation and implementation procedures	ZESCO – Zambia and ESKOM – South Africa	Sept. 2004	10 days	TANESCO	Mr. Mansur Rashid
25.	Study Tour on EMS formulation and implementation procedures	ZESCO – Zambia and ESKOM – South Africa	Sept. 2004	10 days	TANESCO	Mr. Joackim Joseph
26.	International Course on African Wetland Management (ICAWM)	Kenya Wildlife Service Training Institute (KWSTI), Naivasha – Kenya	13th Oct. – 23rd Nov. 2004	43 days	TANESCO	Mr. Joackim Joseph
27.	Mining and the Environment	Lulea, Sweden	Sept. 20 – Oct. 15, 2004	4 Weeks	NEMC	Mr. Danford Mwaipopo
28.	Water Resources Management, Data Processing and Analysis	IMTR, Nairobi – Kenya	Sept. – Nov. 2004	3 Months	TANESCO	Ms. Joyce Nzali
29.	International Course on African Wetlands Management	KWSTI, Naivasha, Kenya	Oct. 13 – Nov, 2004	2 Months	TANESCO	Mr. Joackim Joseph
30.	International Training Course on	Sweden	Sept. 20 – Oct. 15,	1 Month	NEMC	Mr. Danford Mwaipopo

	Mining and the Environment		2004			
31.	IUCN The World Conservation Union	Bangkok, Thailand	Nov. 2004	2 Weeks	NEMC	Dr. M. A. K. Ngoile
32.	IUCN The World Conservation Union	Bangkok, Thailand	Nov. 2004	2 Weeks	TAWIRI	Dr. Charles Mlingwa
33.	Record Management	National Institute Productivity (NIP) – Morogoro	Nov. 2004	4 Weeks	NEMC	Ms. Anna Chale
34.	Record Management	National Institute Productivity (NIP) – Morogoro	Nov. 2004	4 Weeks	LKEMP	Ms. Yolanda Turuka
35.	Record Management	National Institute Productivity (NIP) – Morogoro	Nov. 2004	4 Weeks	LKEMP	Ms. Sharifa Bakari
36.	Office Management and Administration	National Institute Productivity (NIP) – Morogoro	Nov. 2004	4 Weeks	LKEMP	Ms. Lillian Somi
37.	Environmental Management and Audit	ACP Institute for Management, Swaziland	26th March – 24th April, 2005	1 Month	NEMC	Mr. Alfred E. Msokwa
38.	Environmental Management and Audit	ACP Institute for Management, Swaziland	26th March – 24th April, 2005	1 Month	Ministry of Energy and Minerals	Mr. Theodore Silinge
39.	Environmental Impact Assessment	The Swedish International Development Cooperation Agency and Rambol Natura AB, Sweden	18th April – 20th May, 2005	1 Month	NEMC	Ms. Zafarani Madayi
40.	25th Annual Conference of the International Association for Impact Assessment (IAIA)	Boston, USA	29th May – 3rd June, 2005	1 Week	NEMC	Mr. Ignace A. Mchallo
41.	Environmental Assessment and Information Management	Kafue Gorge Regional Training Centre (KGRTC), Kafue Gorge, Republic of Zambia	13th – 24th June, 2005	2 Weeks	TANESCO	Mr. Ng'anzi J. Kiboko
42.	STREAM Flow Modelling	International Water Management Institute (IMWI), Kenya	27th June – 1st July, 2005	2 Weeks	TANESCO	Mr. Stansilaus Kizzi
43.	STREAM Flow Modelling	International Water Management Institute (IMWI), Kenya	27th June – 1st July, 2005	2 Weeks	RBWO	Mr. Willie Mwaruvanda
44.	Hydropower and the Environment	International Centre for Hydropower, Trondheim, Norway	Sept. 5th – 22nd , 2005	18 days	Ministry of Energy and Minerals	Mr. Theodore Silinge

45.	Hydropower and the Environment	International Centre for Hydro-power, Trondheim, Norway	Sept. 5th – 22nd , 2005	18 days	Ministry of Energy and Minerals	Mr. Leornard Masanja
46.	Hydropower and the Environment	International Centre for Hydro-power, Trondheim, Norway	Sept. 5th – 22nd , 2005	18 days	TANESCO	Mr. Maneno Katyega

Appendix 9 MUAJAKI, SEMA-Ki and CMP - Objectives

MUAJAKI

Overall Project Objective: Avoid increase in health problems during construction. Areas of concern; STDS, including HIV, malaria, infectious diseases, maternal and childhood health problems, substance and alcohol abuse, and traffic- and construction-related accidents and health hazards.

Specific Objectives for transition during operation:

- Strengthen capacity and competence within District Health Departments in Mufindi and Kilombero for continued monitoring and mitigation.
- Facilitate establishment of partnerships and collaboration between districts and key national and international agencies, organisations and processes that can support the districts.
- Work towards establishing a sustainable funding mechanism for continued monitoring and mitigation of health impacts in the communities surrounding LKHP.
- Promote and contribute towards the development of a Tanzanian policy regarding assessment, monitoring and mitigation of health impacts in connection with infrastructure development projects.

Residual impacts expected during operation;

(a) Continued transmission of malaria in upstream communities.
(b) Continued high risk for transmission of HIV/AIDS due to long incubation times of the disease.
(c) Lack of preventive and curative health services due to large population increase.

SEMA-Ki

Overall Project Objective: To safeguard the welfare of the people in the communities around the Lower Kihansi Hydropower Project (LKHP) in terms of promoting and/ or sustaining such aspects as health, education, housing, access to land, water and participation in decision making during and after construction.

Residual impacts expected during operation:

(a) Migrant workers opt to remain in the area.
(b) Opportunistic business community takes advantage of easier access
(c) Migrant workers married to locals may bring in extended family raising population pressure.
(d) Unsuccessful opportunistic job seekers

CMP

Based only in the Kihansi River Catchment the Catchment Management Plan had the **Overall Objective:** Achieve effective management of the Kihansi catchment, based on a well functioning catchment management system.

More specifically CMP aimed to achieve the following objectives:
- Train villages to carry out environmentally sustainable managment of soil and water resources.
- Support local district institutions to monitor hydrological state of catchment.

Beneficiaries of the project were 14 villages in the Kihansi River catchment (Ukami, Uhafiwa, Ihimbo, Mapanda, Ilogombe, Igeleke, Kibengu, Kipanga, Mbawi, Ny'ngula, Masisiwe, Nyawengete, Boma la ng'ombe, Mwatasi). These villages cover two districts Mufindi and Kilolo of Iringa region.

In 2003 CMP identified a number of impacts that remain to be mitigated for a fully established management plan. Three main areas requiring mitigation were local capacity and competence building, institutional arrangement and improving services.

Appendix 10 Sustainability of MUAJAKI, SEMA-Ki and CMP

Continuation of MUAJAKI Activities by local government after project closure

Activity initiated under MUAJAKI	Effectiveness of transfer to local government (Continued or discontinued)
Upland Malaria (Uhafiwa and Ukami)	
Provision of health education on malaria or local communities and individuals	Some education is provided but with few staff (8 for district) it is not adequate
Provision/ distribution of bed nets	There is a national effort to distribute nets to pregnant mothers at a subsidized cost. For the rest population nets are commercially available at Tshs 3,500,-.
Support to malaria case management in local clinics	Malaria case management in local clinics has ceased
Monitoring of vector habit	No information
Monitoring of malaria transmission	There is no monitoring of malaria transmission
Monitoring of malaria morbidity	No information obtained during site visit
Monitoring of malaria mortality	This is done in clinics and information feeds into to district reports
STDS/HIV	
Provision of health education for local communities and individuals on STDs/HIV	Education provided but low staff numbers and lack of facilities
Condoms marketing	Condoms available in shops at reduced cost. No marketing of condoms
Technical and material support to STD clinics	Lack of technical and material support on STDs/HIV in clinics both on the lowland and in the catchment. Clinics do not conduct voluntary counselling and testing services for HIV although training was provided.
Provision of Voluntary counselling and testing services for HIV	Although trained, clinics do not conduct voluntary counselling and testing services for HIV.
Material distributed on health/ behaviour change in the communities	Distribution of materials on health / behaviour change in the communities has ceased after project closure.
Training for local and district assistants.	No local and district health assistants have been trained after the project.
Clinics (health centres and dispensaries) rehabilitated	No clinic or health centre has been rehabilitated post LKHP construction , most unfinished buildings remain unfinished to date.
Introduction of cost sharing in local clinics	Has been introduced but communities unable to meet costs
Regular inventories of units and equipment	No regular inventories of units and equipment.
Dissemination of Maternal and Child health information to TBAs and Local clinics	Facilities for maternal and child health services in all villages visited inadequate due to low numbers of staff and technical facilities.
Regular household visits to monitoring STD/HIV and malaria under MUAJAKI	Not continued due to lack of human and financial resources

Continuation of SEMA-Ki activities by local government after project closure

Activity initiated under SEMA-Ki	Effectiveness of transfer to local government (Continued or discontinued)
Market facilities	Only for lowland villages. Access to market is a problem in the catchment
Water for domestic use	Yes water remains a significant problem (See txt)
Dissemination of knowledge and skills that allow exploitation of natural resources in a sustainable manner	Established woodlots in catchment not doing so well, lack of seedlings and poor marketing facilities Training has been discontinued
Education on know how for economic improvement	This is not done effectively due to poor staffing
Sensitisation on how to handle influx populations	Has been discontinued
Training village government on sustainable development for communities	Discontinued due to lack of resources
Initiated social amenities infrastructure	No additional social amenities infrastructure has been constructed post project.
Environmental committees	There is an active environmental committee in all villages that participates in patrolling the catchment forest, and woodland, establishing and managing nurseries, checking for incidence of fire and raising awareness. No additional committees have been formed after the phasing out of the SEMA-Ki.
Training for tree seed nursery care	There is no training or technical support available
Establishment of active micro finance groups in communities	All micro finance groups ceased to exist.
Workshops for capacity enhancement in the community through District staff (e.g. charcoal stove making, how to write/run mini projects etc.)	Activity discontinued.
Act as a platform to generate recommendations for mitigation to LKHP	Post project, the communities have no platform to generate recommendations for mitigation to LKHP
Mediation of disputes and misunderstandings between LKHP and the communities	In the absence of a platform this is not possible. Disputes channelled through village governments
Promotion of small scale development related assistance provided to the communities	Not available
Periodic monitoring of changes in local amenities	Not done
Involved youth and women groups involved in economic activities	Has been discontinued

Activities of CMP continued by Local Government after project closure

Activity initiated under CMP	Effectiveness of transfer to local government (Continued or discontinued)
Awareness raising on environmental issues	This is continued
Establishment of water user groups	There are water user groups in all villages even on lowland, but they are not active
Preparation of village PRAs which include issues of natural resource management	Was completed under the CMP
Training of paraprofessionals	Has been discontinued, though district staff are sporadically given some training
Procurement of work gear	District does not have sufficient funds to meet all requirements
Establishment of village based environmental committees	These continue to function but have no technical or financial support from District or LKHP/ LKEMP
Establishment of grass root voluntary groups	
Aawareness campaigns in communities close to reservoir	This continues, the CMP vehicle was handed over to the District to facilitate such activity
Distribution of soil conservation and afforestation material (seeds etc.)	Discontinued for lack of funds
Provision of technical support for improved tree planting	Not done
Establish monitoring protocols for livestock movement	Not mentioned

Appendix 11 Template for Client's Follow-up

No.	Consultants' Recommendation	Client's Comments	Follow-up action	Date
Kihansi Gorge Ecosystem				
1	Introduction of a double tank system for all three spray wetlands;			
2	Measurement of pressure and installation of filters;			
3	Mechanism to allow rapid purchase of spare parts;			
4	More frequent pressure checks on each sprinkler during the rainy season;			
5	More frequent cleaning of sedimentation ponds;			
6	WD should abide with the Water Act of 1974 Section 15.			
7	Introduce sprinkler precipitation measurement into the monitoring regime.			
8	Improve safety conditions of the Gorge maintenance;			
9	Conduct EIA for all planned research related infrastructure prior to the finalization of their design plans.			
10	Further training of the Gorge Technicians			
11	Reports of studies and consultancies should be routinely shared with the RAMPO office;			
12	Give RAMPO more flexibility to take decisions relating to day to day management of activities in the Gorge, e.g. control over sufficient funds to purchase spare parts;			
13	The water quality meter should be repaired to facilitate measurement of turbidity;			
14	Make provisions for periodic testing sediments, BOD, COD, and bio-monitoring and monitoring of organic substances used as pesticides or fertilisers should be made;			
15	Repair and replace RBWO and LKEMP data loggers.			
16	Conduct Chytrid studies using 'swabbing' technique on amphibians to investigate prevalence of Chytrids in the Gorge.			
17	Improve enforcement of bleach foot bathing procedures			
18	Take preventive measures to address theft of equipment			
19	Ensure wider and timely sharing of information gained from Captive Breeding programme			
20	Establish database and website to ensure accessibility of information to all parties			

No.	Consultants' Recommendation	Client's Comments	Follow-up action	Date
21	Extension of scholarship programme to include funding and activities for conservation education at primary and secondary schools in LKHP adjacent communities.			
Vegetation				
22	Further study is required to monitor if there are changes in vegetation characteristics with the current flow regime.			
23	The RAMPO should be trained further particularly on aspect of plant identification..			
24	Establishment of the baseline and scientific protocol on epiphylls monitoring.			
Kihansi River Hydrology				
25	Explore possibilities of using rectangular open channel to countercheck flow from the bypass pipe;			
26	RBWO should download data from the loggers on monthly basis for effective monitoring water flows in the Kihansi river;			
27	RBWO need to improve reading and collection of data from the river gauge station by providing transport to the responsible staff;			
28	Staff gauges installed at river stations need to be used to calibrate the data loggers;			
29	Specific training is required for the RAMPO to carry water quality monitoring;			
30	The river water need to be tested against sediments, BOD, COD, and also biomonitoring e.g levels of phytoplankton;			
31	Research and Consultancy reports need to be routinely shared with the RAMPO office.			
32	Field testing of water quality need to follow closely the Tanzanian Water Utilization Regulation. This will include monitoring of organic pollution introduced artificially and organic pollution of natural origin.			
33	Specific training is required for the RAMPO to carry water quality monitoring;			
34	The river water need to be tested against sediments, BOD, COD, and also biomonitoring e.g levels of phytoplankton;			
35	Research reports to be routinely shared with the RAMPO office.			
36	Field testing of water quality need to follow closely the Tanzanian Water Utilization Regulation. This will include monitoring of organic pollution introduced artificially and organic pollution of natural origin.			
37	As proposed in the EMP it is important to have standard procedure for monitoring seismic events and structural stability of the			

No.	Consultants' Recommendation	Client's Comments	Follow-up action	Date
	dam, standard procedures for monitoring sedimentation rate in the dam and release of sediments from dam during flushing operations.			
38	Repair dam monitoring tools presently no functioning, i.e. piezometers			
39	Correct inconsistencies in the reporting on the total number of gauging stations;			
40	A more consistent presentation responsi-bilities/ownership of the various gauging stations would be desirable;			
41	Verify to what extent foreign technology can be replaced by simple, locally available technology so that parts and spare parts for various equipment can be obtained at more reasonable prices;			
42	Consider, a change in management structures, favouring those closer to the operations as it may yield efficiency gains. Including recruitment of resident technician			
43	Correct inconsistencies in the reporting on the total number of gauging stations;			
44	A more consistent presentation responsi-bilities/ownership of the various gauging stations would be desirable;			
45	Verify to what extent foreign technology can be replaced by simple, locally available technology so that parts and spare parts for various equipment can be obtained at more reasonable prices;			
46	Consider, a change in management structures, favouring those closer to the operations as it may yield efficiency gains.			
47	Clarify (or delete if not applicable any more) the requirement in the EMP that TANESCO and RBWO should exchange hydrological and hydraulic data on the Kihansi river on real time basis.			
Erosion, Fire Control, and Waste Management				
48	There should be standard procedures for monitoring erosion and re-vegetation of the excavated land;			
49	There is an urgent need to stringent prevention and control of fires; in this context the practices of cultivation of land surrounding LKHP area by TANESCO staff may also be reviewed.			
50	There is need to have Engineer or Technician responsible for environmental mitigation measures at the LKHP work site.			
51	There is a need to establish solid waste standard monitoring procedures, which will assist to improve solid waste management at the work sites.			

No.	Consultants' Recommendation	Client's Comments	Follow-up action	Date
52	Waste disposal should be treated as s a long-term issue and it is reasonable to expect that at least non-burnable, non-biodegradable waste be carried outside the Gorge. Certainly, all plastic waste should be carried out. This policy needs to be made clear to staff and visitors. Tins could be washed, collected, and another porter hired to carry down such a load.			
53	Liquid waste from the camp dispensary and clinic need to be tested for appropriate treatment before entering to the domestic water treatment system.			
Occupational Health & Safety				
53	Any deficiencies from the company policy described in Chapter 7 should be rectified;			
54	Institutional responsibility for Health issues needs clarification;			
55	Reports from Field Office need swift follow-up action from Headquarters, or otherwise decision making responsibility decentralized in order not to delay important security measures.			
56	The managerial procedures for safety concerns needs to be significantly revised to provide for more effective and direct response to the various security concerns.			
57	Pest control measures should be taken.			
58	The managerial procedures for safety concerns needs to be significantly revised to provide for more effective and direct response to the various security concerns.			
59	Pest control measures should be taken.			
60	The suspension bridge at the bottom of the Gorge needs to be strengthened and made more stable,			
61	The Latrines need to have a basic roof and each "squatting plate" should be made stable;			
62	The hole of the pit latrine needs to be kept covered in the interests of cleanliness and disease control;			
63	A first aid kit needs to be kept in the Gorge, as does a stretcher, thus facilitating evacuation. Staff needs to be given basic training in first aid;			
64	The RAMPO and Gorge technicians be made aware of the symptoms of Rickettsia and medical personnel associated with the project also receive this information, and on treatment.			
Institutional Aspects				

No.	Consultants' Recommendation	Client's Comments	Follow-up action	Date
65	Revise/Amend the EMP to include a clear monitoring plan in the form of a logical framework. This would include clear targets to be achieved. At the same time the EMP should be adjusted to simplify and clarity the reporting system.			
66	Establish an annual monitoring cycle with institutional work plans that define the responsibility for data collection for the agreed indicators			
67	Conduct an annual review process, during which the key parties involved in the EMP implementation submit their annual monitoring reports			
68	NEMC/LKEMP to establish and up-date regularly a repository for all data collected through studies and consultancies conducted under the framework of the LKHP. Make data widely available through a website and distribute hard-/soft copies to immediate users. Dissemination shall include the public in LKHP locality (this requires a public version in Kiswahili for non scientists)			
69	A review of the institutional set up of the LKEMP with a view of full inclusion of all relevant stakeholders and more complete and timely sharing of information;			
70	Public disclosure of environmental monitoring results and studies undertaken by LKEMP. The public includes not only the national and international research community but also village communities around Kihansi and elsewhere in Tanzania.			
71	Long-term institutional responsibilities for the Kihansi area to be clarified;			
72	The process of granting the land title to be finalized.			
73	TANESCO, involving other stakeholders, is encouraged to carefully plan and set aside funds for decommissioning incorporating lessons learned and best-practise from other projects.			
Socio-economic Aspects				
74	In addition to the LWCP, a conservation plan that focuses on the lowland communities would mitigate environmental degradation in the lowland.			
75	The establishment of a platform to deal with community concerns related to LKHP.			

Appendix 12 List of references

Environmental Newsletter, Special Issue: Featuring the Lower Kihansi Environment Management Project (LKEMP): Succeses and Challenges, January-June 2005, Issue No. 1, Vol. 7.

Government of the United Republic of Tanzania: Act Supplement No. 6, The Land Act, May 1999.

Government of the United Republic of Tanzania: Bill Supplement No. 9, The Environmental Management Act, July 2004.

Lower Kihansi Environmental Management Project: Assessment of By-pass Flow at Kihansi Dam Site, November 2004.

Lower Kihansi Environmental Management Project: Dry Season Intermittent High Flow Manipulations, March 2003.

Lower Kihansi Environmental Management Project: Intermittent High Flow Manipulations and Ecological Studies, Interim/Preliminary report, March 2003.

Lower Kihansi Environmental Management Programme: Participatory Rural Appraisal for Chita and Mlimba villages in Kilombero District, Final report, February 2005.

Lower Kihansi Environmental Management Programme: Participatory Rural Appraisal for Igeleke and Mapanda Villages Mufindi District, Final report, February 2005.

Lower Kihansi Environmental Management Programme: Report of Participatory Rural Appraisal for Ng'ingula, Masiswe & Bomalang'ombe Villages in Kilolo District, Final report, February 2005.

Lower Kihansi Environmental Management Project: The Preparation of a Hydrological Monitoring Programme for Compliance with the Water Right Condition for the Lower Kihansi Hydropower Project, Final report, December 2003.

Lower Kihansi Environmental Management Project: Updated Environmental Management Plan for the Lower Kihansi Hydropower Project, June 2004.

Ministry of Energy and Minerals: the National Energy Policy, February 2003.

Ministry of Lands and Human Settlements Development: National Land Policy, 1997.

Ministry of Water and Livestock: Building Capacity to Implement an Environmental Flow Programme in Tanzania, Report of an training workshop in Tanzania, November 2003.

Ministry of Water and Livestock: National Water Policy, July 2002.

Ministry of Water and Livestock: Water Utilization: Control and Regulation, Amendment 1981.

National Environment Management Council: Consultancy Services for Preparation of a Landscape Wide Conservation Plan for the Upstream Kihansi Catchment, Final report Vol. II Appendices, September 2005.

National Environment Management Council: Landscape Wide Conservation Plan for the Upstream Kihansi Catchment, Final report: Vol. I Main report, September 2005.

National Environmental Management Council: Lower Kihansi Environmental Project, Final report, November 2003.

Tanzania Electric Supply Company Limited: Lower Kihansi Hydropower Project.

Vice Presidents Office: National Biodiversity Strategy and Action Plan, August 2001.

Evidence

LKEMP: Request for Information with Regards the Environmental Audit for the Lower Kihansi Hydropower Facility.

LKEMP: Reports of the Captive Breeding programme no 3 – 12.

MTAC Meeting: Overview of the DRAFT Updated Environmental Management Plan for the Lower Kihansi Hydropower Project, March 2004.

Mufindi District Council: Final Report of Mitigation Projects, 1996-2003.

Mufindi District Council: HIV/AIDS in District (Status). No date.

Mufindi District Council: HIV/AIDS Monitoring, January-December 2004.

Mufindi District Council: Malaria Monitoring, January-December 2004.

Mufindi District Council: The Programme of Small Scale Mitigation Activities at Kihansi, July 2003.

National Environment Management Council: Baraza La Taifa La Hifadhi Na Usimamizi Wa Mazingira, July 2004.

National Environment Management Council: Monitoring and Evaluation of the Lower Kihansi Environment Management Project, February 2004.

National Environment Management Council: Oversight Monitoring of the Lower Kihansi Environmental Management Project, December 2004.

National Environment Management Council: Report on the Monitoring and Evaluation of the Lower Kihansi Environment Management Project, August 2003.

NORPLAN: Drawing No. 100-01 Sprinkler System. No date.

NORPLAN: Kihansi CMP Semi-Annual Report, 2003.

Rufiji Basin Water Office: Gauging Station ”Sitrep”, Sheet No. 1. No date.

Rufiji Basin Water Office: Recommendations by RBWO – Iringa Office. No date.

Rufiji Basin Water Office: Safari Report: Kihansi River at Lutaki and Below Dam Site, June 2004.

Rufiji Basin Water Office: Safari Report: Low Flow Measurements and Reconaissance Survey for Construction of Cable Way – Kihansi River at Below Dam Site – 1 KB/NEW, January 2005.

Rufiji Basin Water Office: Safari Report: Work Report on Gauge Installation and Calibration of Weir at Kihansi Dam Site Bridge Inspection, and Data Collection from River Gauging Stations, July 2005.

Tanzania Electric Supply Company Limited: CMP – Phase 2: Implementation of the Catchment Management Plan: Agricultural Activities, Final report, February 2002.

Tanzania Electric Supply Company Limited: Immediate Rescue and Emergency Measures: Instructions for the Maintenance of the Artificial Spray Systems in the Kihansi Gorge.

Tanzania Electric Supply Company Limited: Delegation of Authority.

Tanzania Electric Supply Company Limited: Health and Safety Policy, January 1995.

Tanzania Electric Supply Company Limited: Lower Kihansi Environmental Management Project: Support for Data Collection and Hydrological Modelling.

Tanzania Electric Supply Company Limited: Lower Kihansi Environmental Programme: Long term Mitigation in the Kihansi Area, Final report, February 2002.

Tanzania Electric Supply Company Limited: Remedial Works to Augment the Minimum Bypass Flow Releases at the Kihansi Pond, Terms of Reference.

The Government of the United Republic of Tanzania

LOWER KIHANSI HYDROPOWER PROJECT

IMMEDIATE RESCUE AND EMERGENCY MEASURES

Final Specialist Report: Amphibian Studies

June, 2002

Date of issue : 2002-06-24

Prepared by : Prof. Alan Channing, Ms. Siobain Finlow-Bates and Mr. Svein Erik Haarklau

Citation: NORPLAN 2002. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Amphibian Studies*. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania

SUMMARY

This report
This report presents the results from the amphibian studies carried out during the IREM project in 2001. Studies have focused most heavily on the Upper Spray Wetland, which was the largest wetland and considered to be the most important area of spray toad habitat.

Core area
The spray toads show a clumped distribution. They may occupy only part of the Upper Spray Wetland, depending partly on humidity and wind speed. Population estimates were determined for this core area.

Sampling power
Sufficient quadrats were sampled to ensure that the population estimation achieved a 50% precision. In cases where the toad density was very low, the number of quadrats sampled was very close to this level.

Population changes
The population in the Upper Spray Wetland showed a statistically significant decline from February to March 2001, and a significant increase from then to October.

Gorge population
The October 2001 mean population estimate for the combined spray wetlands of the Kihansi Gorge was just over 11 000. In June 2001 this was approximately 13 000. In March 2002 the estimate was almost 12 000.

Index of Abundance
Mean daytime counts on the 13 permanent rock plots in the Upper Spray Wetland correlate significantly with the Upper Spray Wetland vegetation population estimate. It will be possible to use this index of abundance as a rapid survey tool.

Day vs night
Spray toads move onto the top of vegetation and onto rock faces after dark. Monitoring should be carried out at similar times of day to be comparable.

Reproduction
Amplexus takes place at the start of the wet season from December to January. Fertilization is internal and the eggs are retained within the oviducts where they develop through the tadpole stage, to be born in February as small versions of the adults. The juveniles are purple with lime-green markings, and feed at the base of the vegetation. They develop into adults with the typical yellow background with brown markings by August. Zoo studies show they can breed at approximately nine months.

Synchronous breeding
The reproductive patterns are shown by toads in all the wetlands simultaneously, showing that the sprinkler system does not disrupt the breeding cycle.

Other amphibians
Only five other amphibian species than the Kihansi Spray Toad were observed to be resident in the Kihansi Gorge Spray Wetlands. These are the Torrent Frog, the Leaf Litter Frog, the Common Squeaker, the Dwarf Forest Toad and the Uluguru Tree Frog. There are almost 30 species of amphibian known from the Udzungwa Mountains.

Intermittent high flows
Flow manipulations with a peak of 8 m^3/s for four hours in the wet season and 4 m^3/s for two hours in the dry season were not observed to result in a change in habitat use by the Kihansi Spray Toad in the Upper Spray Wetland. Longer periods of testing would be required in order to obtain more conclusive results.

Sprinkler and walkways	The sprinkler systems and walkways installed in the spray wetlands have improved the habitat markedly. The conditions are approaching the pre-diversion state and the walkways are preventing trampling.
Adult age	Skeletochronology of a 28 mm female toad shows no growth rings, suggesting that the toads may only live for one year as adults. However, a uniform food-rich habitat through the year might prevent the formation of the lines of arrested growth.
Skin	The spray toads have thin skin with relatively few warts and smaller granular glands than similar bufonids like the dwarf forest toad.
Weights and lengths	Females are significantly larger than males. Both males and females showed significant increases in length from April to August. Recruitment of juveniles and subadults produced a significant decrease in mean size of individuals in October.
Vocalisation	A sound spectrogram of the advertisement consists of one to four pulses at a pulse rate of 167/second. The emphasised frequency is 4.4 kHz.
Seasonality	The spray toads show a peak in breeding during the wet season, and a colour change and water storage in the bladder during the dry season. The toads aggregate in high density on rocks along the river in the dry season.

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List of abbreviations/acronyms

CI	: Confidence Interval
IREM	: Immediate Rescue and Emergency Measures at LKHP
KfW	: Kreditanstalt für Wiederaufbau
KST	: Kihansi Spray Toad
LAG	: Line of Arrested Growth
LEMP	: Long-term Environmental Monitoring Programme at LKHP
LKHP	: Lower Kihansi Hydropower Project
LLSW	: Lower Lufulutonya Spray Wetland
LSW	: Lower Spray Wetland (in the Kihansi Gorge)
MFSW	: Main Falls Spray Wetland (in the Kihansi Gorge)
MGSW	: Mid-gorge Spray Wetland (in the Kihansi Gorge)
MSW	: Mhalala Spray Wetland (in the Kihansi Gorge)
MTAC	: Multi-disciplinary Technical Advisory Committee
NEMC	: National Environmental Management Council
NORAD	: Norwegian Agency for Development Co-operation
Sida	: Swedish International Development Co-operation Agency
sp.	: species
TANESCO	: Tanzania Electric Supply Company Limited
UDSM	: University of Dar es Salaam
ULSW	: Upper Lufulutonya Spray Wetland
USW	: Upper Spray Wetland (in the Kihansi Gorge)

1 INTRODUCTION AND BACKGROUND

1.1 Background to IREM project

The Immediate Rescue and Emergency Measures project aims to study the options for, and where possible to implement, mitigation measures for the protection of biodiversity in the Kihansi Gorge, in particular the Kihansi Spray Toad and its ecosystem. The mitigation measures to be considered are less costly alternatives to the continuous minimum bypass flow of 7.7 m^3/s. This bypass flow has been recommended as a desirable mitigation measure on environmental grounds but at this time would impose great costs on Tanzanian society through resultant load shedding and rendering the Lower Kihansi Hydropower Project economically unviable.

A Joint Donor Supervision Mission, with representatives from the World Bank, NORAD, Sida, KfW and TANESCO carried out in October 2000 identified the need for an immediate, short-term project aimed at protecting the Kihansi Spray Toad and the spray wetlands that support it. In early November 2000 NORPLAN was requested to prepare a proposal immediately. NORAD and Sida provided grant funding for the project in mid December 2000.

After discussions the Multidisciplinary Technical Advisory Committee (MTAC), established with representatives from various Tanzanian ministries and authorities, a project document was agreed upon and a contract between the Tanzania Electric Supply Company Ltd. (TANESCO) and NORPLAN A.S was signed in late March 2001. The IREM project is a short-term one-year project.

The IREM project contains the following 10 components;

1) Studies of intermittent high flow
2) Artificial irrigation/sprinkling
3) Construction of walkways in the Kihansi Spray Wetlands
4) Ecological studies of the Kihansi Spray Toad
5) Studies of the Mhalala Spray Wetland
6) Searching for / investigation of translocation of the Kihansi Spray Toad
7) Kihansi Area Conservation Plan
8) Institutional capacity needs assessment
9) Initial preparation of water right
10) Technical reviews and appraisals

1.2 Objectives

The objectives for the amphibian studies are:

1. To assess the effectiveness of implemented and proposed mitigation measures

2. To improve the level of understanding of the biology and ecology of the Kihansi Spray Toad in order to assist in the formulation and implementation of mitigation measures to protect the species

1.3 Background to amphibian studies and the Kihansi Spray Toad

Discovery

The Kihansi Spray Toad (*Nectophrynoides asperginis*) was first discovered in December 1996 in the Upper Spray Wetland and formally described in 1998 (Poynton *et al*., 1998). The species is only known to inhabit a number of small spray wetland areas in the Kihansi Gorge. The total habitat of the species is extremely restricted – about 2 hectares (20 000 m^2).

Genus distribution

The genus *Nectophrynoides*, a member of the family Bufonidae, occurs only in Tanzania. All six species described and assigned to this genus are restricted to montane environments. These are *Nectophrynoides asperginis* (Kihansi/Udzungwas), *N. cryptus* (Ulugurus), *N. minutus* (Ulugurus), *N. tornieri* (Usambaras, Ulugurus, Udzungwas), *N. viviparus* (Ulugurus, Udzungwas, Porotos, Mt Rungwe), and *N. wendyae* (Udzungwas).

Existing knowledge

The first review of the biology and distribution of the toad was published as part of the species description (Poynton *et al.*, 1998). Some information was given on egg size, and the female type specimen was reported to contain 16 embryos. The difference in size between developing embryos in three females examined led to the conclusion that there is a prolonged breeding season in this species. No other information on biology had been published when the IREM project started in January 2001.

Pre-diversion population estimate

Population size in the Upper Falls Spray Wetland in October 1998 was estimated at 8 648 in an area of 2 025 m^2 (Howell *et al*., 1998, Poynton *et al*., 1998).

Habitat area

In July 2000 it was estimated that the area receiving natural spray in the Kihansi Gorge had decreased by about 98% from the December 1999 situation, with the Upper Spray Wetland having decreased by 96% (World Bank, 2000a). In October 2000, with the Main Falls Spray Wetland included, an estimate of a reduction in habitat of around 92% was made (World Bank, 2000b).

Conservation status

The genus *Nectophrynoides* has been accorded the highest level of protection, being listed by CITES in Appendix I (as *Nectophrynoides* sp., listed 1 July 1975). The genus is also controlled through the USA Endangered Species Act. Within Tanzania the Wildlife Conservation Act, act 1974 No. 12, requires a permit to capture any animal.

The Kihansi Spray Toad, although not subjected to a formal assessment, meets the IUCN classification of Critically Endangered, detailed below using the IUCN 2000 criteria (IUCN, 2000):

1) A1 – An inferred population reduction of over 90% in the last 10 years.
2) B1a – Known to exist only in a single small area.
3) B1b – Decline in habitat quality and number of mature individuals.

It is probably one of the most critically endangered amphibians in Africa, based on the very small area of habitat and the loss of spray.

Reproduction

All members of the genus *Nectophrynoides* investigated are ovovivipa-rous; the eggs are fertilised internally, and retained in the oviducts during development through the tadpole stage. The young are born alive as small versions of the adults.

Climate

The Kihansi Spray Toad appears to be completely dependent on the spray zones created by the Kihansi Falls in the Kihansi Gorge. The effec-tive removal of the spray zones (with the possible exception of the Mha-lala Spray Wetland) as a result of diversion of the Kihansi River was ex-pected to have major impacts on micro-climatic conditions and also on the Kihansi Spray Toad. A variety of studies have already identified the potential impacts of climate change on amphibians (Donnelly and Crump, 1998).

2 MATERIALS AND METHODS

2.1 Sampling of the Kihansi Spray Toad

Studies of amphibians, mainly the Kihansi Spray Toad, were carried out using a combination of different counts and observations throughout 2001 (See table 2-1):

- Day and night-time counts on permanent rock plots established in the Upper Spray Wetland;
- Counts in quadrats along transects in the spray wetland vegetation in the Upper, Lower, Mid-gorge, Main Falls and Mhalala Spray Wetlands;
- Counts of Kihansi Spray Toads on accessible rock faces in the Upper, Lower, Mid-gorge, Main Falls and Mhalala Spray Wetlands;
- General observations of toad behaviour in the Upper, Lower, Mid-gorge, Main Falls and Mhalala Spray Wetlands;
- Night observations in the Upper and Lower Spray Wetlands.

Brief visits with opportunistic counts and observations have been made in the Jabali intake and Lower Gorge Spray Wetland areas. Other spray zone locations within the Kihansi Gorge have been visited, without finding the Kihansi Spray Toad.

Other commonly used methods of monitoring populations as well as studies of individuals (movement, mortality), such as mark-recapture techniques, were discussed initially but not used. The small size of the toads makes marking difficult. A severely reduced population of the critically endangered spray toad also meant that handling of the toads should be kept to a minimum to reduce stress levels and reduce the risks of disease spreading. There was concern that capturing, marking and handling could affect survival rates of the spray toad. It also appears that many individuals have a very limited range over the period of a single sampling session and apparently little movement and mixing of individuals occurs. This would also suggest that mark-recapture is not a suitable means of monitoring the population.

Table 2-1 Overview of amphibian sampling carried out in the Kihansi Gorge under the IREM project in 2001.

Date of sampling	**Location**	**Perm. rock plot counts**	**Vegetation transects (plots)**			**General observations**	**Comments**
			Inside sprinkler	Outside sprinkler	Total		
January (23rd – 26th)	Upper Spray Wetland	2	NA (not installed)	–	–	Yes	Before IREM contract signed. Planning visit.
	Lower Spray Wetland	NA	–	–	–	Yes	
	Mid-gorge Spray Wetland	NA	–	–	–	Not visited	
	Main Falls Spray Wetland	NA	NA (not installed)	–	–	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	
February (7th – 14th)	Upper Spray Wetland	10	NA (not installed)	40	40	Yes	Before IREM contract signed. 37 plots on rocks close to Kihansi River in Upper Spray Wetland.
	Lower Spray Wetland	NA	–	–	–	Yes	
	Mid-gorge Spray Wetland	NA	–	–	–	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	–	–	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	
March (31st) – April (4th)	Upper Spray Wetland	10	111	28	139	Yes	IREM signed 22nd March. Found spray toad in Lower Gorge Spray Wetland (approx. 350 m a.s.l)
	Lower Spray Wetland	NA	–	–	–	Yes	
	Mid-gorge Spray Wetland	NA	–	–	–	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	10	10	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	
April (25th) – May 6th)	Upper Spray Wetland	16	75	0	75	Yes	Length/weight data for spray toads collected in Upper Spray Wetland. Controlled flow manipulations were planned, but the extremely high river flow made this impossible.
	Lower Spray Wetland	NA	–	–	–	Yes	
	Mid-gorge Spray Wetland	NA	12	8	20	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	-	-	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	
June (2nd – 20th)	Upper Spray Wetland	43	300	68	368	Yes	Length/weight data for spray toads collected in Upper Spray Wetland. Flow manipulations carried out 5th – 13th June. Total count on rocks in MFSW.
	Lower Spray Wetland	NA	27	6	33	Yes	
	Mid-gorge Spray Wetland	NA	–	–	–	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	10	10	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	

Table 2–1 cont.

Date of sampling	**Location**	**Perm. rock plot counts**	**Vegetation transects (plots)**			**General observations**	**Comments**
			Inside sprinkler	Outside sprinkler	Total		
July (9th – 12th)	Upper Spray Wetland	13	–	–	–	Yes	Permanent rock plots counted during sampling for vegetation studies.
August (9th – 18th)	Upper Spray Wetland	29	135	17	152	Yes	Length/weight data for spray toads collected in USW and MFSW. Flow manipulations carried out 11th – 15th August.
	Lower Spray Wetland	NA	–	–	–	Yes	
	Mid-gorge Spray Wetland	NA	21	1	22	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	10	10	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	–	–	Yes	
August (19th) – September (3rd)	Upper Spray Wetland	13	–	–	–	Yes	
October (16th – 22nd)	Upper Spray Wetland	10	121	42	163	Yes	Length/weight data for spray toads collected in USW and MFSW. Total rock counts in all 5 spray wetlands.
	Lower Spray Wetland	NA	41	23	64	Yes	
	Mid-gorge Spray Wetland	NA	37	5	42	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	29	29	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	33	33	Yes	
December (1st – 7th)	Upper Spray Wetland	18	132	45	177	Yes	Length/weight data for spray toads collected in Upper and Main Falls Spray Wetlands.
	Lower Spray Wetland	NA	38	10	48	Yes	
	Mid-gorge Spray Wetland	NA	39	0	39	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	22	22	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	0	0	Yes	
March (2nd – 5th) 2002	Upper Spray Wetland	6	135	20	155	Yes	
	Lower Spray Wetland	NA	39	0	39	Yes	
	Mid-gorge Spray Wetland	NA	36	0	36	Yes	
	Main Falls Spray Wetland	NA	NA (not installed)	26	26	Yes	
	Mhalala Spray Wetland	NA	NA (not installed)	0	0	No	

2.1.1 Upper Spray Wetland

General

The Upper Spray Wetland, which is the largest spray wetland area and the area was assumed to support the majority of the Kihansi Spray Toad population (World Bank, 2000a), has been the focus for amphibian studies carried out under IREM and has thus been most intensively monitored and studied. This wetland was expected to provide the best source of data with the least disturbance to the habitat and the spray toad population.

Habitat type was stratified, splitting the spray wetlands into wet rock habitat and wetland vegetation habitat, to reduce the variance in the population estimates.

Permanent rock plots

Two sets of permanent rock plots have been established in the Upper Spray Wetland. The rock plots were marked by drilling holes (6 mm diameter) in the rock faces and attaching metal expansion bolts (10 cm long) with numbered plates in the holes. Firstly there is a set of 13 plots, each approximately 1 m x 1 m and, secondly, 8 larger rock faces (covering a total area of just over 55 m^2) where the number of Kihansi Spray Toads and other frogs are counted. The 13, 1 m^2 rock plots, mostly found on vertical rock faces, were located at the centre on larger rock faces within the wetland. The rock plots are spread across the wetland where rocks occur. An overview photo of the plot locations is given in Figure 2-1. A detailed description, including photographs of the permanent rock plots is given in Volume III of the Final IREM Report.

Counts have been carried out mostly during daylight with some night-time counts. In relation to the flow manipulation testing sessions in June and August counts were made before, during and after the flow manipulations. As far as possible frogs were identified as juveniles, sub-adults and adults. Gravid females and pairs in amplexus were also noted. Counts and observations have been carried out using a standardised recording sheet, shown in Figure 2-2. An overview of the timing of permanent rock plot counts is given in Table 2-1.

All rock plots are within the sprinkler system. With the exception of an area of rocks close to the Kihansi River, which receives natural spray even under minimum bypass alone, rock faces outside the sprinkler are dry and without any spray toads. The rock faces closest to the river are devoid of spray toads in periods of high river flow due to strong winds and heavy spray.

A total of about 170 counts were carried out during 11 sampling sessions. An overview of the timing and number of permanent rock plot counts is given in Table 2-1.

Vegetation transects

Frog counts in 0.5 m x 0.5 m (0.25 m^2) quadrats along transects in the spray wetland vegetation have been carried out in the Upper, Lower, Mid-gorge, Main Falls and Mhalala Spray Wetlands. The relatively small size of the plots, which results in low numbers of toads per plot, was chosen to minimise the chance of toads escaping the plot before being encountered and give statistically stronger data sets (more plots). The distance between the centres of the quadrats was approximately 2.5 m, sometimes 2.0 m when the sampled wetland area was small. Although randomly located plots would improve the statistical power of the counts it was decided that plots located along transects would be more appropriate as trampling damage to the habitat of the critically endangered spray toad would be less.

The majority of the plots were inside the sprinkled area as this is the area with most spray toads, but some plots were located outside the sprinkled area for comparison. In relation to the flow manipulation testing sessions in June and August counts were made before, during and after the flow manipulations.

Transects were usually placed perpendicular or parallel to the Kihansi River. Perpendicular transects usually started at the western end (closest to the river), going across the gradient of spray and wind from the Kihansi River. Counts were carried out using 4 sticks, each 0.5 m long, which were used to measure and mark the corners of the plots. Vegetation was carefully and gradually removed, with some short stops in the vegetation removal in order to observe any movement in the vegetation. Encountered frogs were removed from the plot and placed outside. Due to differences in the type and density of vegetation cover between the plots the time used to search each plot varied and a fixed searching time was not employed. Searching continued until all vegetation within the plots had been checked or removed. This means that the sampling is quite destructive for some of the plots (see Photograph 2-1). Any removed vegetation was carefully replaced once the plot was searched.

All vegetation counts were carried out during daylight hours. As far as possible frogs were identified as juveniles, sub-adults and adults. Gravid females and pairs in amplexus were also noted. Counts and observations have been carried out using a standardised recording sheet, shown in Figure 2-3.

To assess the impact of the sprinkler system a control area was established where the spray generating nozzles were switched off. The control area was not established at the very start of the project period due to concerns about the recovery of the spray toad population. For a period after the control area was supposed to be established problems during and after maintenance activities meant that the area did not work as a proper control until after the dry season flow manipulations in August.

During the 8 sampling sessions from February 2001 to March 2002 where vegetation counts were carried out, a total of about 1 269 plots have been counted in the Upper Spray Wetland, of which 1 009 (includes control area) were located within the sprinkler system and 260 plots outside the sprinkler system. An overview of the vegetation sampling sessions is given in Table 2-1.

Night observations

In addition to the permanent rock plot counts carried out at night, general observations were made of the Kihansi Spray Toads in the Upper Spray Wetland at night. General information on behaviour, vocalisation, activity levels, etc. was collected. Detailed counts of the movement of the Kihansi Spray Toad onto rock faces at dusk, and from rock faces at dawn, were also recorded in March, June and August.

Other observations

A total rock count was made during day-time in the Upper Spray Wetland in October and December. Some day and night-time observations on the west bank of the Kihansi River, just opposite the Upper Spray Wetland, were also made.

2.1.2 Lower Spray Wetland

Permanent rock plots

Due to the extremely small population of Kihansi Spray Toads in the Lower Spray Wetland at the start of the IREM project permanent rock plots were not established in this locality.

Vegetation transects

Once night observations indicated that the number of Kihansi Spray Toads had reached a reasonable level in June, vegetation transects were carried out. Vegetation transects were carried out in June, October and December. Transects were placed perpendicular to the Kihansi River, in between and parallel to the sprinkler lines. The same methodology with 0.25 m^2 plots as that used in the Upper Spray Wetland was applied (see above). Table 2-1 summarises the counts made in this spray wetland.

Night observations

Night observations were carried out throughout the year in the Lower Spray Wetland.

Other observations

A total rock count was made during day-time in the Lower Spray Wetland in October. Some day-time observations on the west bank of the Kihansi River, just opposite the Lower Spray Wetland, were also made.

2.1.3 Mid-gorge Spray Wetland

Rock counts

No permanent rock plots were established in the Mid-gorge Spray Wetland as there are very few accessible rock faces available for the plots. Total day-time rock counts were carried out in October.

Vegetation transects

Vegetation transects were made at various intervals during the year (April/May, August, October). Transects were carried out in parallel to the Kihansi River, which is also parallel with the sprinkler lines. A total of 159 plots were counted, of which 145 were inside the sprinkler system. Table 2-1 includes a summary of the counts made in this wetland.

Night observations

Night observations were not carried out in this wetland due to the difficulty of accessing the area.

2.1.4 Main Falls Spray Wetland

Rock counts

No permanent rock plots were established in the Main Falls Spray Wetland due to limited accessibility. Total rock counts were carried out in June, August and October.

Vegetation transects

Vegetation transects were made at various times during the year (March/April, June, August, October, December). Accessibility was initially a limiting factor. A total of 107 plots were counted during the sampling sessions. Table 2-1 summarises the counts made in this wetland.

Night observations

Night observations were not carried out in this wetland due to the difficulty of accessing the area.

2.1.5 Mhalala Spray Wetland

Mhalala is the most undisturbed spray wetland remaining in the Kihansi Gorge. As such it was not considered appropriate to carry out intensive sampling in this wetland which would cause damage to this important area. Additionally, the Mhalala Spray Wetland is very small in size and particularly prone to damage since the soil cover is very thin and the slope very steep.

Rock counts

No permanent rock plots were established in the Mhalala Spray Wetland. Total rock counts were carried out in October 2001 for comparison with the counts carried out by the World Bank Review Mission in October 2000 (World Bank, 2000b).

Vegetation transects

Vegetation transects were carried out in October 2001 for comparison with the counts carried out by the World Bank Review Mission in October 2000. A total of 33 plots was counted.

Night observations

Night observations were not carried out in this wetland due to the difficulty of accessing the area and to minimise activity and damage.

2.2 Core area and population estimates

2.2.1 Core area

During counts of spray toads in vegetation plots carried out in 2001 it was noted that at any particular time of the year the spray toads occupied only part of the area within the Upper Spray Wetland. This area changed in size and space through the year. This was termed the core area. The core area concept has been used as the basis for the analysis of data collected at different times of the year. The other Kihansi Gorge spray wetlands have also shown this spatial and temporal variation in habitat use and the core area concept has also been applied here. Once the counts in the vegetation were completed for the sampling session the core area could be defined by marking the plots counted on a sketch map (See Figure 2-4). The core area was then used in conjunction with the average density of spray toads in order to obtain a population estimate.

Population estimate

Mean density on the permanent rock plots and in the vegetation was used to arrive at an estimate for the spray toad population in the rock habitat and the vegetation habitat of the Upper Spray Wetland. Average density in the two habitats is simply multiplied by the core area of each habitat to arrive at a total population estimate. The density of spray toads per plot obtained in sequential sampling sessions was tested to see if they were statistically different.

Comparative estimates

The vegetation counts show that the toads have a clumped distribution. This is statistically described as a negative binomial distribution. Population estimates within 95% confidence limits were determined for the vegetation of the Upper Spray Wetland. As the transects extended across the whole wetland, it was possible to make comparative estimates with counts taken before 2001.

The methods for determining the statistical distribution follow Krebs (1999) using ECOLOGICAL METHODOLOGY (Exeter Software). For comparative purposes, all the counts from the Upper Spray Wetland vegetation available to us were used. For each count the mean density and 95% confidence intervals were determined. As all the counts showed a negative binomial distribution, the power of the estimate was assessed by determining the number of quadrats that need to be counted in order to achieve a 50% precision of the mean. This value is normal for ecological work (Krebs, 1999).

The purpose of the power analysis is to evaluate if sufficient quadrats have been counted in order to achieve a mean within 50% of the confidence interval. Core area is not taken into account, and all the quadrat data from the wetland are used.

Index of abundance

The 13 permanent rock plots are marked and toads can be easily counted. The counts from these plots were correlated with vegetation population estimates. If the rock plot data produce a reliable index of abundance this can be used for rapid tracking of population size and change in the future.

2.3 Other amphibians

Incidental observations were made on other amphibians in the Spray Wetlands during studies of the Kihansi Spray Toad. Specific sampling for amphibians other than the Kihansi Spray Toad was not carried out. Other amphibian species present were the Forest Dwarf Toad (*Nectophrynoides tornieri*), the Torrent Frog (*Arthroleptides* sp.), the Leaf Litter Frog (*Schoutedenella xenodactyla*), the Common Squeaker (*Arthroleptis stenodactylus*) and the Uluguru Tree Frog (*Leptopelis uluguruensis*). Some individuals of three species found in or around the spray wetlands probably represent accidental introductions, the Fornasini's Spiny Reed Frog (*Afrixalus fornasinii*), the Spotted Reed Frog (*Hyperolius puncticulatus*) and Grey Tree Frog (*Chiromantis xerampelina*). These were probably carried in from the lowland with the equipment and supplies used to construct the sprinkler system and related structures.

During the March/April visit the number of Leaf Litter Frogs (*Schoutedenella xenodactyla*) was remarkably high in the Upper Spray Wetland. The density and population estimates of this species are compared to those of the Kihansi Spray Toad, as they may represent potential competitors for food, particularly of juvenile spray toads.

2.4 Other specialist studies

Information collected as part of the other specialist studies should be read together with this report. These studies include data on insects, vegetation, micro-climate and spray characteristics (NORPLAN, 2002a;b;c). The specialist reports should be consulted for methods, detailed results and discussion.

2.5 Intermittent high flows

The effect of changes in the daily bypass flow regime on the distribution and behaviour of the Kihansi Spray Toads was determined experimentally during June and August 2001.

2.5.1 Wet season flow manipulations

Wet season flow manipulations were carried out in June 2001. A regime of 8 m^3/s between 11:00 and 15:00 and 2 m^3/s for the remainder of the day was operated for 9 consecutive days (5^{th}–13^{th}). Vegetation transects were carried out before (127 plots), during (133 plots) and after (108 plots) to monitor the spray toad population in the Upper Spray Wetland. Counts of the permanent rock plots were also carried out throughout the period.

As the flow increased the first day (5th June) of the flow manipulations a person wearing a wet suit was also present close to the plunge pool of the upper part of the Main Falls to observe the response of the spray toads and whether washing away of toads appeared to be a problem. Similarly, a large rock face next to the western arm of the upper part of the Main Falls was counted before and after the increase in flow this day.

2.5.2 Dry season flow manipulations

Dry season flow manipulations were carried out in August 2001. Due to the low levels of reservoirs in the hydropower system it was not deemed possible for TANESCO to operate the same regime as during the dry season. Instead a regime of 4 m^3/s between 11:00 and 13:00 and 2 m^3/s for the remainder of the day was operated for 5 consecutive days (11th–15th). Vegetation transects in the Upper Spray Wetland were carried out before the dry season manipulations. However, due to the short period for which they were operated it was not deemed appropriate to carry out full counts during and after the manipulations. Instead limited vegetation counts were carried out at the edge of the utilised habitat in order to assess whether there had been any movement of spray toads. If there appeared to be evidence of movement further counts could be carried out. Counts of the permanent rock plots were also carried out throughout the period.

2.6 Sprinkler system

Under the IREM project sprinkler systems were installed as mitigation measures in three spray wetlands affected by diversion of the Kihansi River – Mid-gorge Spray Wetland, Lower Spray Wetland and Upper Spray Wetland. The sprinklers aim to maintain micro-climatic conditions in the spray wetland similar to those created under natural conditions. Further details about the design of the sprinklers and when they were installed can be found in Volume II of the main IREM Final Report (NORPLAN, 2002d).

The sprinkler system was monitored frequently during the visits. An attempt was made to determine if the sprinklers were producing suitable spray. Problems with the system were noted.

The vegetation transects were counted within the area covered by the sprinkler system, with control transects beyond the sprinkler system in order to obtain information from the area not covered with artificial spray. The quadrats were located with reference to the sprinkler lines.

In addition, an area of the sprinkler was switched off in August 2001 in order to establish a control area. This area was sampled for comparison with the experimental (sprinkled) area in October 2001 and again at the start of December 2001.

2.7 Search for / translocation of the Kihansi Spray Toad

Searches were undertaken on foot and by air for areas with waterfalls where spray wetlands might be found. Details about the searches for the Kihansi Spray Toad can be found in Volume II of the main IREM Final Report (NORPLAN, 2002e).

2.8 Skeletochronology

The age structure of the population has major implications for the expected rate of population recovery should positive changes in the habitat be effected. The question asked was "how old are large adult toads?". In many amphibian species age can be determined by looking at the microscopic structure of the bones. Lines of arrested growth (LAGs) can be seen in cross section and are formed annually during the season of slow growth. In some species that hibernate, bone resorption occurs when the animal is not feeding, and can be detected.

Toe clips were taken from a large toad with a body length of 28 mm, and from a 22 mm individual. The samples were fixed, decalcified using nitric acid, embedded in paraffin wax and a series of 10 micron sections was cut. These were mounted on glass slides and stained either with eosin and haematoxylin, or Mallory's Azan.

The process of preparing the sample is detailed in Appendix A of this report.

2.9 Skin structure

The Kihansi Spray Toad is similar in overall skin morphology to the related forest species *N. tornieri*, but the latter has a much rougher dorsal surface. The question we asked was: "What is the structure of the skin of the spray toad?" The skin of toads in the family Bufonidae is typically warty and glandular, serving primarily a waterproofing function, and secondarily a defensive function based on the many biochemically active substances secreted (Channing, 2001). Skin structure is related to the ability of the species to withstand desiccation.

A piece of dorsal skin (1 mm x 5 mm) was removed from preserved museum specimens of *N. asperginis* and *N. tornieri*. Each sample was fixed, embedded in paraffin wax and cut into serial sections each 10 microns thick. These were mounted on glass slides and stained with eosin and haematoxylin.

The process of preparing the sample is detailed in Appendix B of this report.

2.10 General morphology

The relationship between gross morphology (e.g. the presence of digital discs) and biology is often taken for granted. Yet, an understanding of morphology helps us to understand how a species is adapted to its environment.

Detailed observations of hand and foot structure were made on specimens of the Kihansi Spray Toad. Drawings were prepared under a Wild M7A stereo microscope using a camera lucida.

2.11 Food

The Kihansi Spray Toad eats very small prey, mostly insects. The proportions of the different items, the identity of the insect prey, and the presence of commensal nematodes in the stomach were determined by

Mr. P. Hawkes. See the entomology specialist report (Volume II of IREM Final Report) for methods and detailed results (NORPLAN, 2002a).

Seasonal availability The relative abundance of two indicator prey species *(Afrosteles distans* and *Ortheziola* sp.) was tracked through the year in the vegetation of the Upper Spray Wetland. See the entomology specialist report for methods and detailed results (NORPLAN, 2002a).

2.12 Length and weight measurements

Samples of toads were taken at different times, and for each the length and weight were determined. Most, but not all, animals were sexed. Snout to tip of urostyle length was measured using a vernier caliper, and approximate weights were determined for small groups of similar sized toads, using an electronic top-loading balance (Ohaus CS-200). The weights were allocated in proportion to the length of the animal. It was not possible to weigh each animal separately as the field balance was only accurate to 0.1 g. Toads were collected from rock faces and from vegetation after dark in the Upper Spray Wetland in May. Toads were also collected from rock faces in the Upper Spray Wetland and Mhalala Spray wetland during the day in August, October and in December. Animals were returned to the area where they were collected.

Note that the entomology specialist report deals with length-weight relationships of a preserved sample used for diet studies.

2.13 General observations of toads and toad behaviour

2.13.1 Observations

Incidental observations were made of aspects of toad behaviour like foraging, feeding, waiting, amplexus and vocalising.

2.13.2 Diel movement

There was a movement of adult frogs on to the rock surfaces at night. In order to investigate this a number of detailed counts were carried out at dawn and dusk during different field visits to monitor the increase and decrease of individuals on one of the permanent rock plots (number 4). These detailed dawn and dusk counts were carried out in March, June and August.

2.13.3 Predation events and potential predators

Potential and actual predators in the spray wetlands were recorded during the ecological studies.

2.13.4 Vocalisation

Calls were noted whenever possible. Recordings of calls were made in the wetland. Despite the problems of spray in the equipment and the background noise of the water, a number of recordings were made. These were analysed using CANARY 1.2.4 – a programme designed for analysing animal sounds, and making accurate comparisons and descriptions possible.

2.14 Photography/filming

35 mm slides

Photographs using 35 mm slide film and paper film were taken to record colour patterns, aspects of the habitat, and the spray toads. Close-up pictures of frogs were taken using a macro lens and a pair of flash units. The camera was also used for general photography.

Digital

Digital pictures and close ups of frogs were taken.

Video

Digital video recordings were made of the falls, the spray over the Upper Falls Spray Wetland, and to show the position and movement of the toads.

A collection of photographs from Kihansi are presented on the CD in Volume III of the main IREM Final Report.

2.15 Sources of variation and uncertainty

Carrying out ecological studies and making population estimates are usually prone to variation.

Compared to an ideal situation the following factors are likely to introduce variation and uncertainty to the studies of the spray toad:

- Variation in detectability of the very small juveniles (Photograph 2-2) compared to the larger subadults and adults, possibly resulting in underestimation of the juvenile population.
- The use of transects can be prone to systematic error since they are inherently non-random.
- Biological censuses are usually prone to some element of observer bias.

In order to reduce these sources of error a group of observers was used wherever possible.

Figure 2-1 Overview of the permanent rock plot locations in the Upper Spray Wetland

Recording sheet for toad counts in Kihansi Gorge Spray Wetlands
Monitoring plots in the Upper Spray Wetland

Date:		Start time:		Stop time:		Observer:	
Weather Conditions:							
Rel. Hum.:	% (logger)	Air temp.:	C (logger)	River Flow:		m^3/s	

Permanent rock plots

Plot no.	Nos. Kihansi Spray Toads (inside plot)							Other amphibians	Crabs	KST out-side plot	Prop. wet (%)	Direct sun-light (Y/N)	Photo, specimen
	Male	Fem.	Subad.	Juv.	Unkn.	Sum	Gravid						
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
Total													

Old Frog Rock

N													
W													
S													
Total													

New Frog Rock

A													
B													
C													
D													
E													
Total													

Comments:

Old Frog Rock:			
North: Spray toads on rock face:		Spray toads on edge/hiding under veg./soil:	
West: Spray toads on rock face:		Spray toads on edge/hiding under veg./soil:	
South: Spray toads on rock face:		Spray toads on edge/hiding under veg./soil:	

Figure 2-2 Standard recording sheet for monitoring of permanent rock plots

Recording sheet for toad counts in Kihansi Gorge Spray Wetlands
Vegetation plots in: Spray Wetland

Date:		Start time:		Stop time:		Observer:	
Weather Conditions:							
Rel. Hum.:	% (logger)	Air temp.:	C (logger)	River Flow:	m^3/s	Plot size:	m x m
Transect Number:		Transect Direction:					
Description of transect location:							

Plot no.	Nos. of Kihansi Spray Toads							Amplexus pairs	Other amphibians	Vegetation	Wet?
	Male	Fem.	Subad.	Juv.	Unkn.	SUM	Gravid				
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
Total											

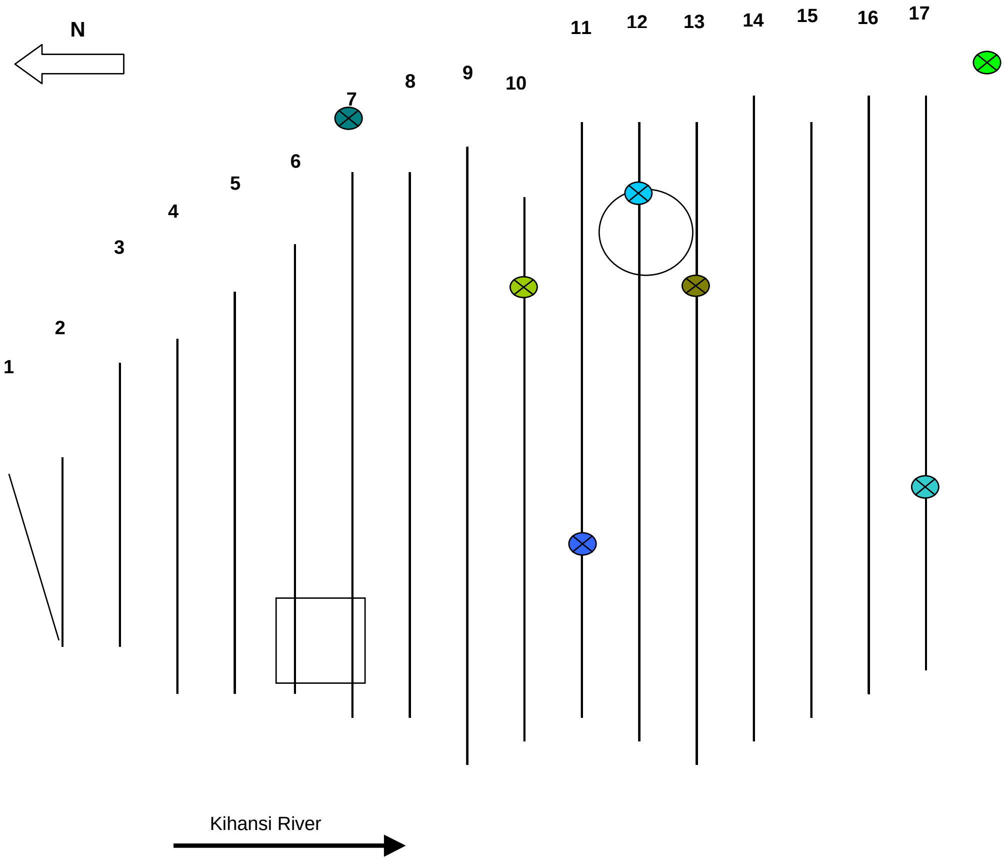
Comments:

Figure 2-3 Standard recording sheet for counts of spray toads in vegetation plots

Vegetation counts in the Upper Spray Wetland

Date:		Time start:		Time end:		Flow:	m3/s
Observer(s):							
No. of transects:		No. of plots:		Size of plots:	0.5 x 0.5 = 0.25 m2		
Comments:							

Tran-sect	No. of KST				No. of plots		
	Juv.	Sub.	Ad.	Sum	In. spr.	Outs. spr.	Sum
1				0			0
2				0			0
3				0			0
4				0			0
5				0			0
6				0			0
7				0			0
8				0			0
9				0			0
10				0			0
Total	**0**	**0**	**0**	**0**	0	0	0



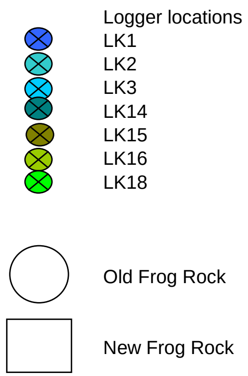


Figure 2-4 *Sketch map of vegetation plots for spray toad counts*

Photograph 2-1 *Example of vegetation plot after spray toad count completed (left) and with vegetation replaced (right).*

Photograph 2-2 *Juvenile Kihansi Spray Toad.*

3 RESULTS

Raw data collected during the amphibian studies are presented on the CD in Volume III of the main IREM Final Report.

3.1 Population dynamics throughout the IREM project

3.1.1 Upper Spray Wetland

Core Area

The core area changed in size and position in the Upper Spray Wetland during the study period. Figures 3-1 to 3-8 illustrate the core area location and size for various field visits.

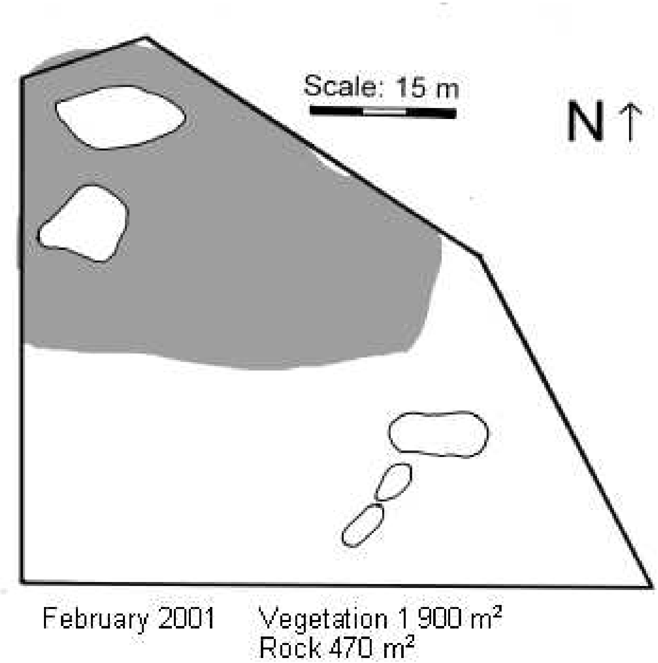


Figure 3-1 *Approximate location of the core area occupied by Kihansi Spray Toads during February 2001 in the Upper Spray Wetland.*

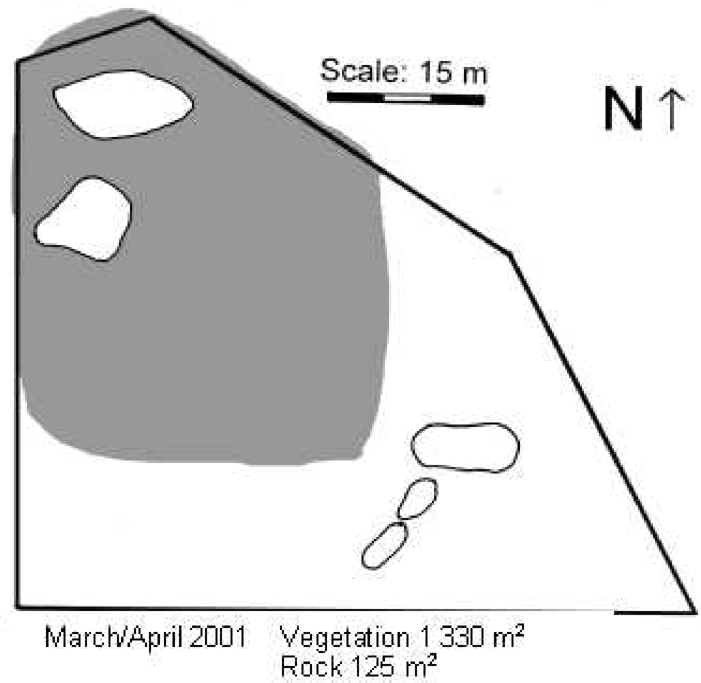


Figure 3-2 *Approximate location of the core area occupied by Kihansi Spray Toads during March/April 2001 in the Upper Spray Wetland.*

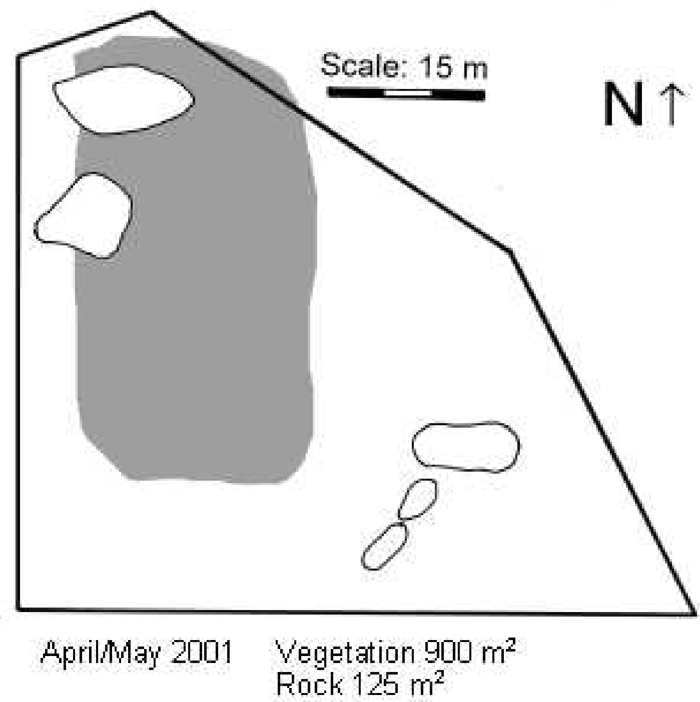


Figure 3-3 *Approximate location of the core area occupied by Kihansi Spray Toads during April/May 2001 in the Upper Spray Wetland.*

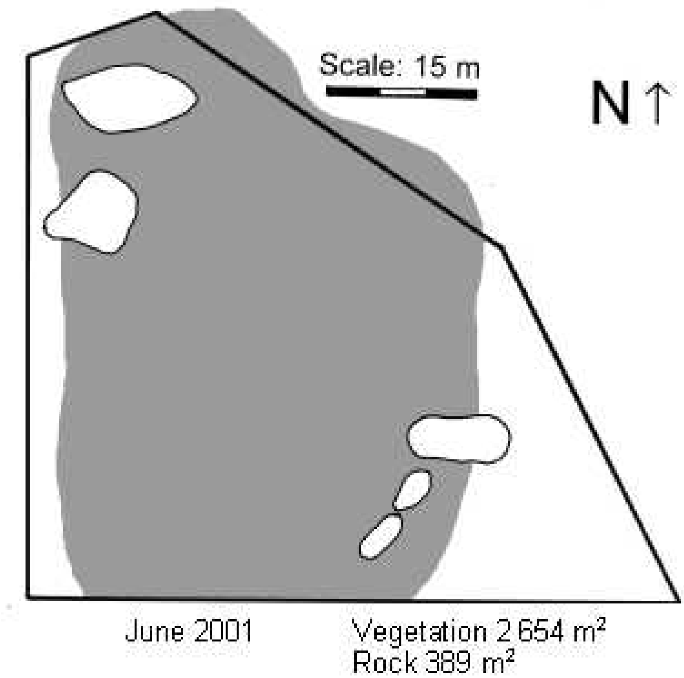


Figure 3-4 *Approximate location of the core area occupied by Kihansi Spray Toads during June 2001 in the Upper Spray Wetland.*

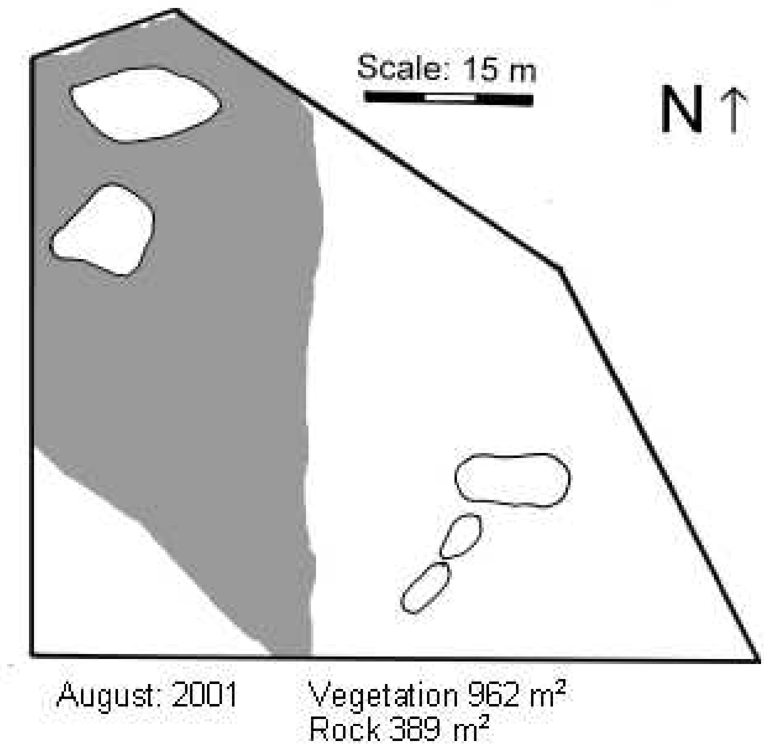


Figure 3-5 *Approximate position and size of the core area occupied by Kihansi Spray Toads during August 2001 in the Upper Spray Wetland.*

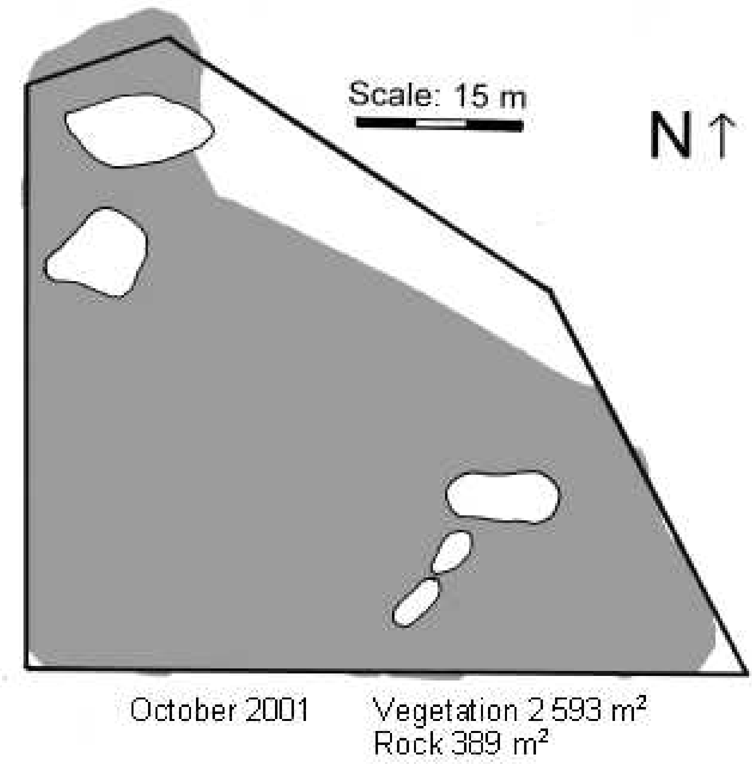


Figure 3-6 *Approximate location of the core area occupied by Kihansi Spray Toads during October 2001 in the Upper Spray Wetland.*

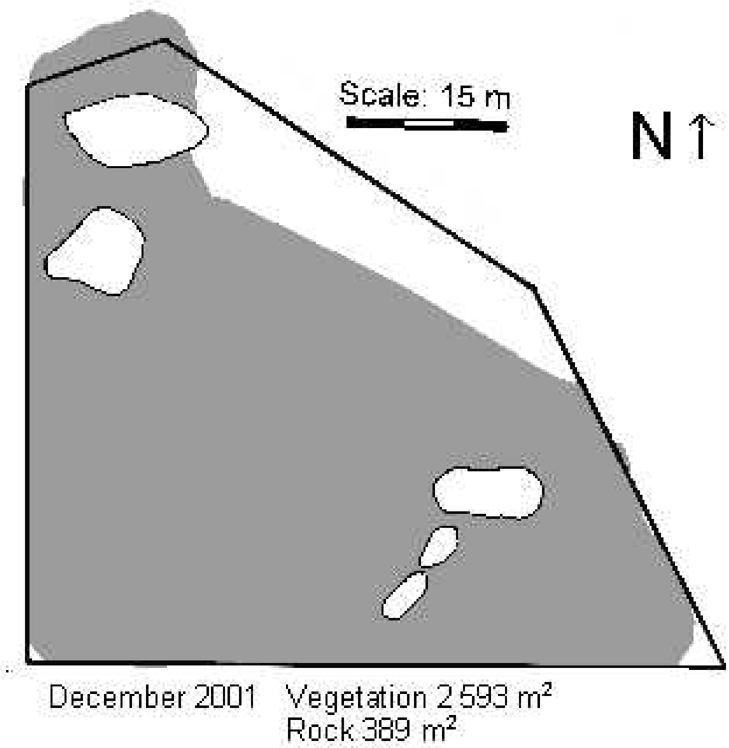


Figure 3-7 *Approximate location of the core area occupied by Kihansi Spray Toads during December 2001 in the Upper Spray Wetland.*

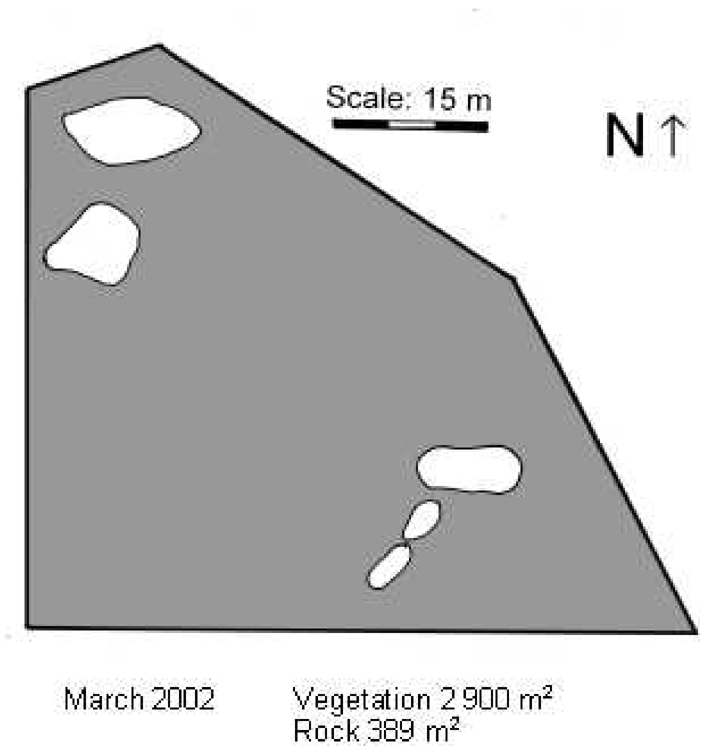


Figure 3-8 *Approximate location of the core area occupied by Kihansi Spray Toads during March 2002 in the Upper Spray Wetland.*

The core area concept permits estimates to be made of the size of a population that occupies more or less of the wetland at different times. In order to compare the patterns in micro-climate and core area, figures were created plotting both core area and temperature and relative humidity for each of the sampling sessions. These figures are presented in Appendix D. With the limited number of loggers and presence of complicating factors it is not possible to investigate the detailed link between the main habitat location and temperature and relative humidity.

During March/April 2001 the core area was centred in the lower part of the wetland, below (west of) Old Frog Rock, covering 38 m along the river x 35 m deep. This was within the area covered by the newly-installed sprinkler system. During the April/May visit, at which time there was over-flow over the LKHP dam and thus higher river flow in the Kihansi Gorge, the core area was further north, covering a band that avoided the strong winds and driving spray blown by the wind generated by the falls. No frogs were found on permanent rock plots 1, 2, 3 and 6 (See Volume III for detailed explanation of location), and it was almost impossible for an observer to make observations near these plots due to the strong winds. During the June visit the population was dispersed throughout the wetland.

The August visit took place during a very dry period. The vegetation core area retracted closer to the base of the falls, covering 962 m^2. This is remarkable, as there was plenty of wet vegetation, and plenty of food insects in the wetland. In terms of relative humidity the conditions in the Upper Spray Wetland do not appear very different between August and October either.

During October the core area covered the complete wetland and a band against the cliffs, except for the unsprinkled control area in the north-east of the wetland. The same core area was observed in December. By March 2002 the core area was observed to cover the entire sprinkler area as the recent rains had increased moisture in the control area.

Population size

The mean density of spray toads in the sample plots in the core area multiplied by the core area has been used to obtain population estimates in the spray wetlands of the Kihansi Gorge. The detailed results of the sample plots and the core area for the Upper Spray Wetland are provided in Appendix E.

Upper Spray Wetland

An overview of the population estimates obtained for the Upper Spray Wetland is given in Table 3-1. The total estimate for the population size within the core area for each field visit to the USW is also shown graphically in Figure 3-9. The October 2000 estimate is obtained from the World Bank data kindly supplied by Dr. W. Newmark.

Table 3-1 *Population estimates for the Kihansi Spray Toad in the Upper Spray Wetland.*

Time	**Core area vegetation (m^2)**	**Vegetation population estimate**	**95% CI**	**Core area rock (m^2)**	**Rock population estimate**	**95% CI**	**Total population estimate in core area**
October 2000 (WB)	578	2 312	0-4 356	284	8553	1 419-8 201	10 865
February	1 900	4 180	2 277-6 083	470	610	119-1 101	4 790
March/April	1 330	1 729	935-2 523	125	23**	13-33	1 752
April/May	900	1 232	440-2 023	125	26**	16-37	1 258
June	2 654	5 073	4 095-6 051	389	168**	136-201	5 241
August	962	2 058	1 382-2 735	389	282**	168-397	2 340
October	2 593	7 097	5 065-9 128	x	521	Total count	7 618
December	2 593	6 733	4 551-8 915	x	572	Total count	7 305
March 2002	2 900	7 602	5 487-9 718	x	60	Total count	7 662

** Estimation based on density of KST on permanent rock plots 1-13
X Not applicable

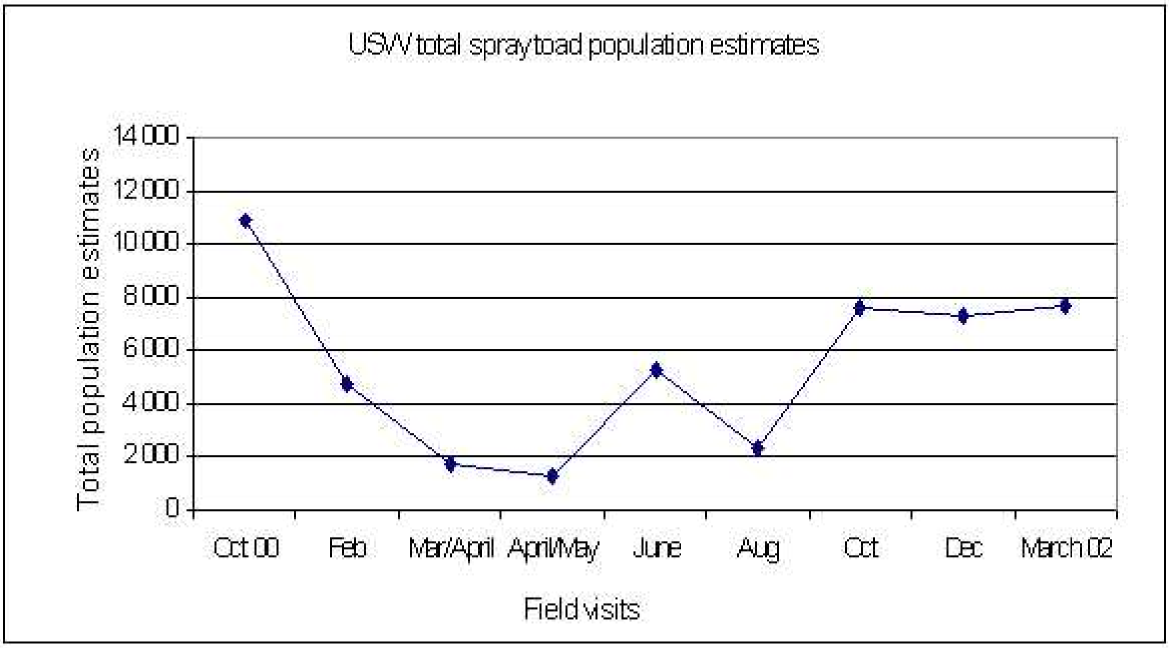


Figure 3-9 *Population estimates for the USW*

Core area

The details regarding the counts in the Upper Spray Wetland and exactly which area was included in the core area are provided in the figures in Appendix E. These figures (using the template shown in Figure 2-4) show the approximate location of the plots counted and which plots are located in the core area, sprinkler area and control area.

Statistics

The statistical significance of the changes in core population estimates were evaluated statistically by comparing the densities of different sampling results, using the Negative Binomial Data Analysis Package (ECOLOGICAL METHODOLOGY). The results of the log-likelihood ratio tests are presented in Table 3-2.

Table 3-2 *Significance of the differences between the core vegetation population density estimates in the Upper Spray Wetland. Probabilities below diagonal, with corresponding Chi-squared values above*

	Feb	Mar/Apr	Apr/May	June	Aug	Oct	Dec	
Feb		2.55					3.1	3.09
Mar/Apr	P=0.1			2.47	3.28	7.04	5.61	6.26
Apr/May	NS	NS				4.01	2.77	2.97
June	NS	P=0.1	NS			4.00	2.58	3.26
Aug	NS	P=0.07	NS	NS			3.46	3.54
Oct	NS	P<0.01	P<0.05	P<0.05	NS			
Dec	P=0.08	P<0.02	P<0.1	P=0.1	P=0.06	NS		
March 02	P=0.08	P<0.02	P=0.09	P=0.07	P=0.06	NS	NS	

Population changes

The estimated decrease in core vegetation population density from February to March/April is statistically significant (p=0.1). The increase from March/April to June is significant (p=0.1). The overall increase from the low point in April/May to the high October, December and March 2002 estimates is significant at the $p<0.05$, $p<0.1$ and $p=0.06$ levels respectively.

The initial decrease in population from February to March/April, followed by the recovery of the population from April/May to the October visit, are therefore shown to be supported statistically.

Power analysis

The estimates of mean per quadrat, 95% confidence interval, number of quadrats required to achieve a precision of 50%, and number of quadrats counted are presented in Table 3-3. Quadrats were all 0.5 x 0.5 m.

Table 3-3 *Statistics for toad sampling in USW vegetation. Most sampling during the IREM project is above, or within the range of 50% precision.*

Date of sample	Estimated mean for quadrats	95% CI	No. of quadrats required for 50% precision	No. of quadrats counted
2001-02-13 (IREM)	0.55	0.25	33	40
2001-04-01 (IREM)	0.19	0.09	132	139
2001-04-26 (IREM)	0.21	0.13	124	75
2001-06-10 (IREM)	0.46	0.14	53	127
2001-08-28 (IREM)	0.30	0.1	79	152
2001-10-15 (IREM)	0.48	0.15	65	163
2001-12-03 (IREM)	0.42	0.14	97	177
2002-03-04 (IREM)	0.64	0.18	56	155

3.1.2 Lower Spray Wetland

During pre-diversion visits general observations (not plot counts) indicated lower density in the Lower as compared to the Upper Spray Wetland (K. Howell, pers. comm.). During the March/April 2001 visit, a night count yielded 24 individuals. At night the toads are more visible, and this count probably represented a relatively large proportion of the actual population.

The estimates for the wetland are presented in Table 3-4, including the World Bank estimate in October 2000.

The core area in June was slightly smaller than 400 m^2. This is just less than one third of the area covered by the sprinkler system.

Table 3-4 Population estimates for the Kihansi Spray Toad in the Lower Spray Wetland.

Time	**Core area vegetation (m^2)**	**Vegetation population estimate**	**95% CI**	**Core area rock (m^2)**	**Rock population estimate**	**95% CI**	**Total population estimate in core area**
October 2000 (WB)	400	-	-	110	763	373-1 153	763
June	400	296	0-2 645	-	-	-	296
October	418	319	*	x	4	total count	323
December	187	374	*	x	7	total count	381
March 2002	0	0	0	0	0	0	0

* The October and December frog counts were too small to determine confidence limits.
- No count
X Not applicable

3.1.3 Mhalala Spray Wetland

This wetland was sampled by the World Bank team in October 2000 (World Bank, 2000b). This is regarded as a vulnerable wetland and no vegetation amphibian counts have been carried out under the IREM apart from a count in October 2001 that serves as a direct comparison with the World Bank count. The estimates for the wetland are presented in Table 3-5.

Table 3-5 Population estimates for the Kihansi Spray Toad in the Mhalala Spray Wetland.

Time	**Core area vegetation (m^2)**	**Vegetation population estimate**	**95% CI**	**Core area rock (m^2)**	**Rock population estimate**	**95% CI**	**Total population estimate in core area**
October 2000 (WB)	220	-	-	28	96	31-161	96
October 2001	152	553	67-759	x	193	total count	746

- No count
X Not applicable

3.1.4 Main Falls Spray Wetland

The highest density of Kihansi Spray Toad was recorded in this small wetland of less than 300 m^2 in June 2001 (20 frogs/m^2). This wetland did not have a sprinkler and was entirely dependent on spray generated from the minimum bypass. The estimated population is presented in Table 3-6.

Table 3-6 Population estimates for the Kihansi Spray Toad in the Main Falls Spray Wetland.

Time	Core area vegetation (m^2)	Vegetation population estimate	95% CI	Core area rock (m^2)	Rock population estimate	95% CI	Total population estimate in core area
October 2000 (WB)	42	-	-	225	470	259-681	470
March/April 2001	260	1 664	146-3 132	-	-	-	1 664
June 2001	260	5 200	2 877-7 176	x	612	total count	5 812
August 2001	200	2 000	156-4 022	-	-	-	2 000
October 2001	40	526	0-2 808	x	237	total count	763
December 2001	40	416	88-700	x	108	total count	524
March 2002	260	1 196	136-1 318	x	53	total count	1 249

\- No count
X Not applicable

3.1.5 Mid-gorge Spray Wetland

During the March/April visit adult and juvenile toads were observed to be present. The available population estimates are presented in Table 3-7.

Table 3-7 Population estimates for the Kihansi Spray Toad in the Mid Gorge Spray Wetland.

Time	Core area vegetation (m^2)	Vegetation population estimate	95% CI	Core area rock (m^2)	Rock population estimate	95% CI	Total population estimate in core area
October 2000 (WB)	210	-	-	59	14	0-41	14
April/May 2001	418	2 592	1 188-3 321	-	-	-	2 592
August 2001	418	1 140	274-1 693	-	-	-	1 140
October 2001	418	1 672	1 028-2 316	x	31	total count	1 703
December 2001	418	1 415	825-2 005	-	-	-	1 415
March 2002	418	2 462	1 591-3 332	-	-	-	2 462

\- No count
X Not applicable

3.2 Index of abundance

Summary data of the permanent rock plots carried out in the Upper Spray Wetland is presented in the raw data CD (Volume III). The mean daytime counts on the 13 permanent rock plots are compared to the Upper Spray Wetland vegetation counts in Figure 3-10, and the regression analysis is shown in Figure 3-11.

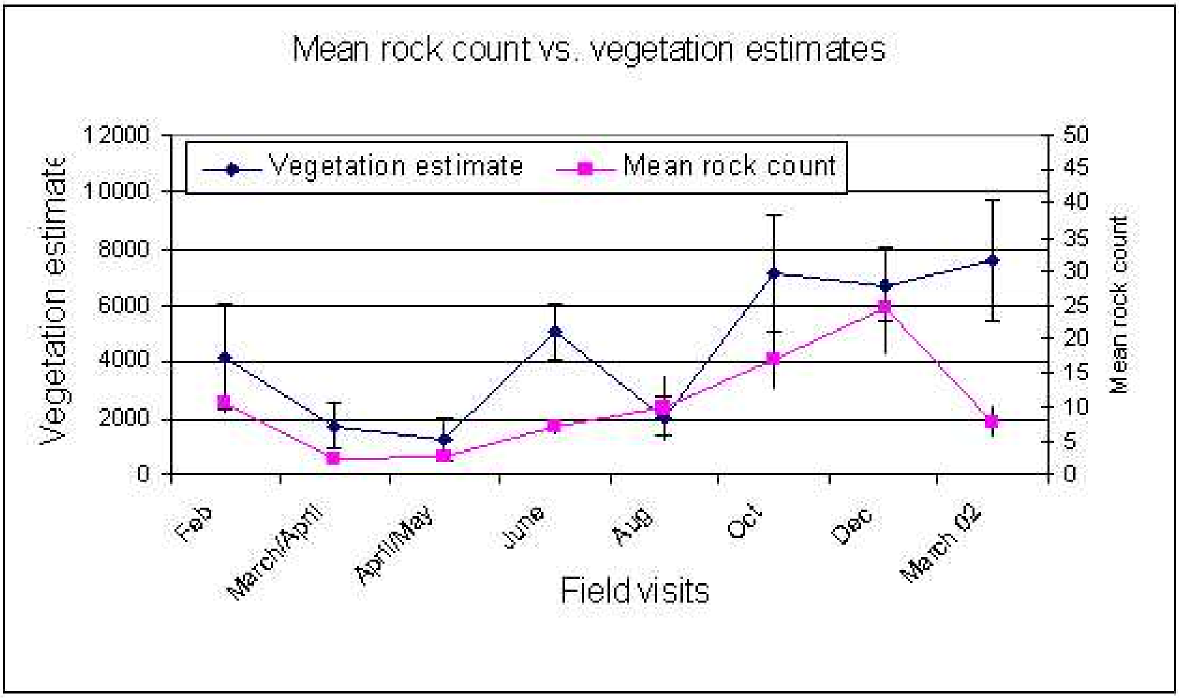


Figure 3-10 *Comparison of mean rock counts and vegetation population estimates in the Upper Spray Wetland during 2001[1]. Vertical bars show 95% confidence intervals.*

The results show that the mean daytime rock count on the 13 permanent rock plots mirrors the changes in population in the wetland vegetation. The high number of juveniles in June increased the vegetation population estimates. Juveniles are never found on rocks, and this may account for the difference between rock and vegetation trends.

The relationship between mean rock counts and the vegetation population estimates can be described by a power curve (Vegetation population estimate = 913.8 (mean permanent rock plot count)$^{0.66}$(Figure 3-11).

[1] June and August figures do not include the counts made during the flow manipulations.

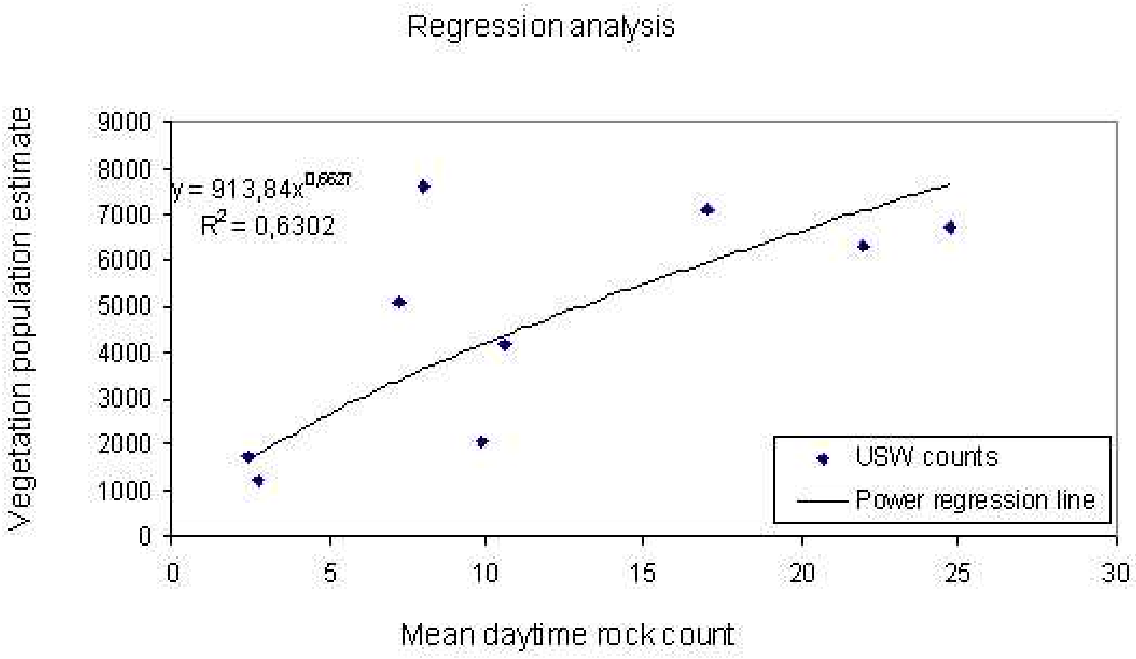


Figure 3-11 *Regression line (power) of the relationship between mean daytime count on the permanent rock plots and the vegetation population estimate for the Upper Spray Wetland.*

3.3 Counts at different times of day

Toads are more visible in the vegetation at night, when they sit on high leaves, presumably foraging. There is also a movement of toads on to rock faces after dark, with a return to the vegetation after daybreak. This is illustrated in Figure 3-12, which shows the activity cycle for toads on permanent rock plot 4 in March 2001. The graph shows the number of toads on the rock face through 24 hours.

The detailed observations of this phenomenon are presented in section 3.14.2.

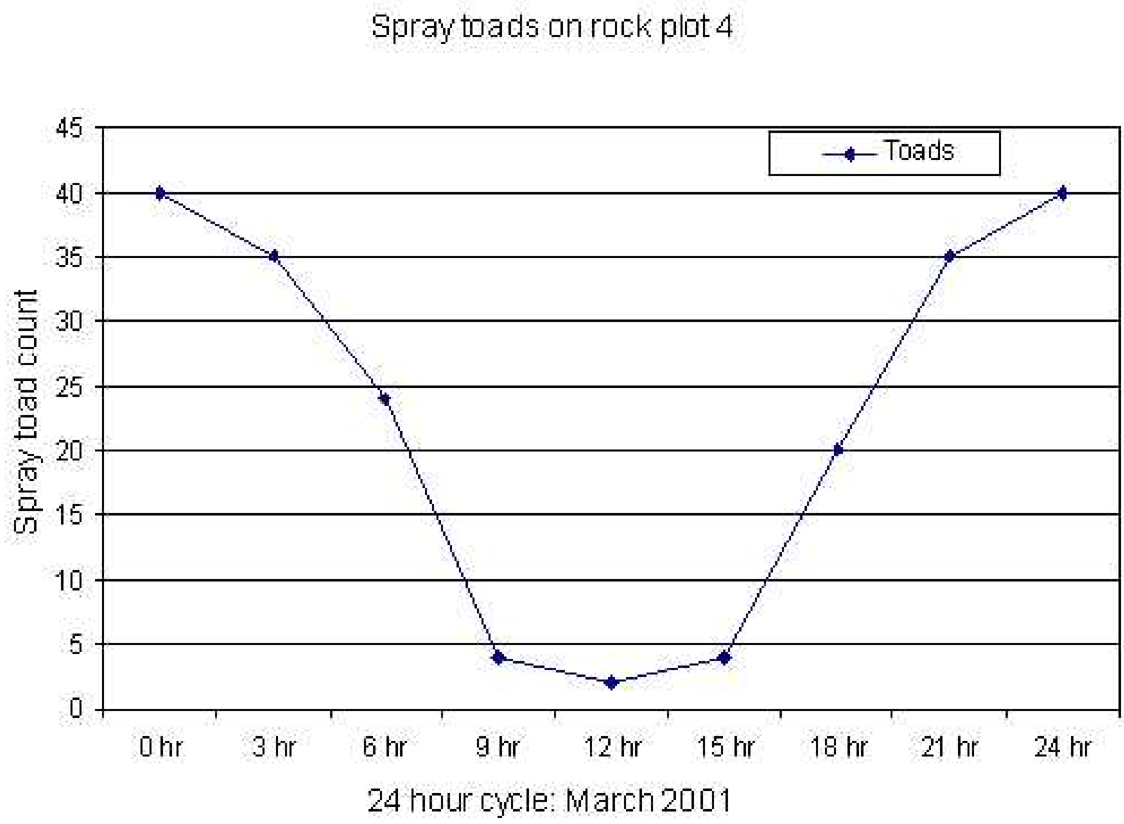


Figure 3-12 *Cyclic presence of toads on rock face of permanent plot 4 in the Upper Spray Wetland.*

3.4 Seasonal reproduction

In the field it is simple to distinguish juveniles, subadults and adults on the basis of coloration and size. Juveniles are purple with lime green markings in the form of irregular longitudinal stripes. The adults are bright yellow with dark brown lateral stripes and a dark sacral blotch. Subadults are intermediate with traces of purple background changing to bright yellow.

The sex ratio was 1:1 in the Upper Spray Wetland. The percentage of females in amplexus, gravid, the proportion of juveniles and the proportion of subadults is presented below.

Females in amplexus

The percentage of females in amplexus in the Upper Spray Wetland is presented for each field visit in Figure 3-13.

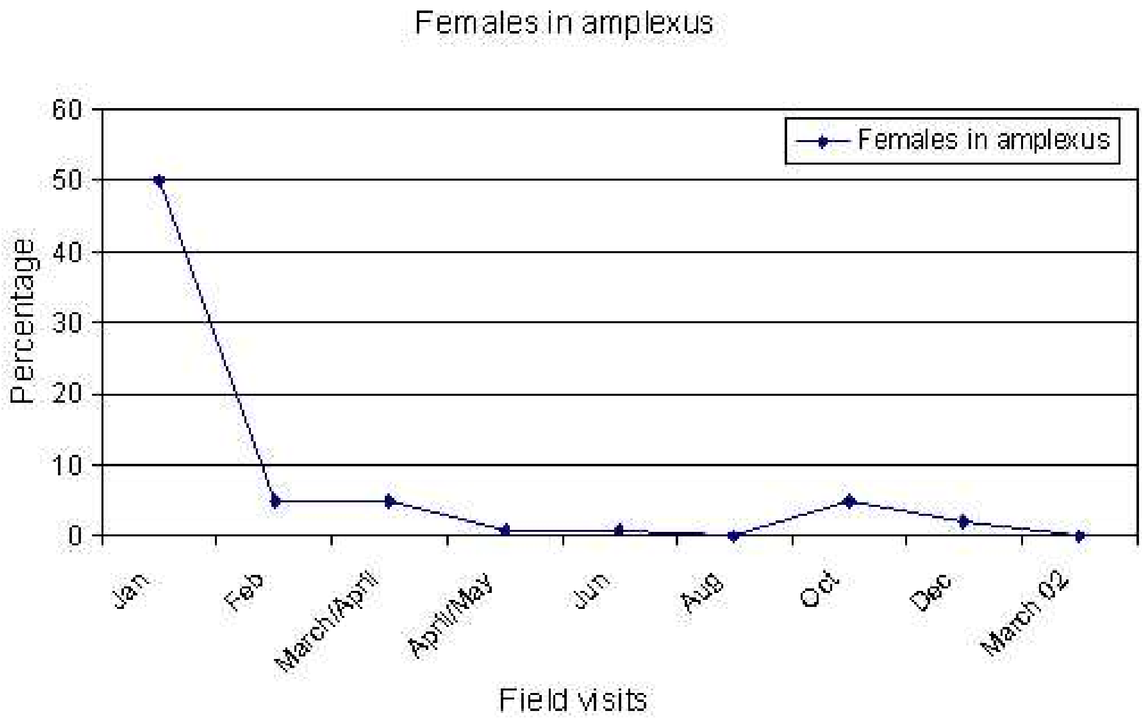


Figure 3-13 *Percentage of adult females in amplexus in the Upper Spray Wetland, 2001.*

Gravid females The percentage of gravid females is presented for each field visit in the Upper Spray Wetland in Figure 3-14.

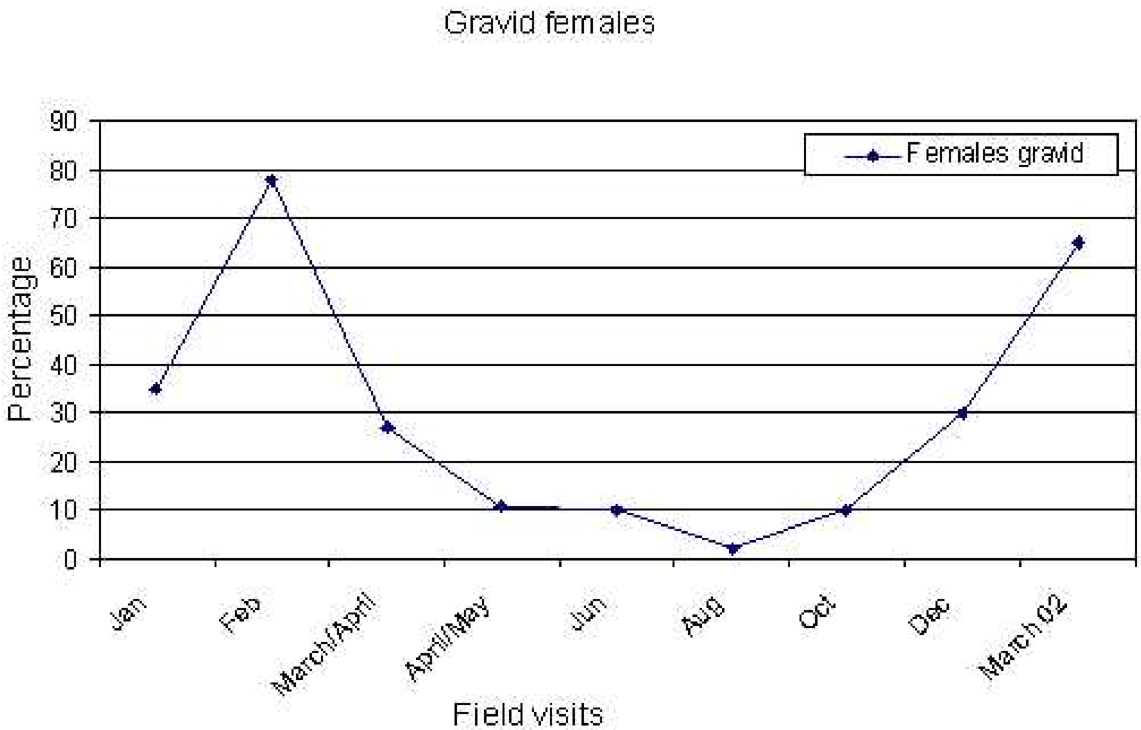


Figure 3-14 *Percentage of females that were gravid in the Upper Spray Wetland, 2001.*

Pseudo-gravid animals During the August/September field visit many individuals showed slight enlargement of the abdomen, and it was difficult to decide in the field if these were gravid females. The examination of a sample of these putatively gravid females using transmitted light and a dissecting microscope permitted the contents of the abdomen to be seen through the thin belly-skin of live animals. Only two of ten females examined were gravid, one with two well-developed juveniles, and the other with early stage 30 tadpoles. The abdomens of all females and one male examined were filled with fluid, suggesting that the bladder is serving as a water-storage organ at this time of the year. See Table 3-8.

Table 3-8 Transmitted-light observations on putatively gravid toads (August/September 2001) in the Upper Spray Wetland.

Length	Sex	Notes
18.0 mm	M	Posterior abdomen filled with fluid. Calling in bag.
25.2 mm	F	Brown with spines. No embryos confirmed. Fluid filled abdomen
23.5 mm	F	Brown with dark-tipped spines. Food in gut. Fluid filled abdomen
23.0 mm	F	Brown, spiny. Food in gut. Fluid filled abdomen
22.4 mm	F	Brown with spines. Embryos visible.
22.0 mm	F	Yellow, partially spiny. Food in gut. Fluid filled abdomen
21.8 mm	F	Dark and spiny. Embryos visible.
22.2 mm	F	Yellow, starting to go brown. No embryos confirmed.
21.0 mm	F	Dark, spiny. No embryos. Fluid filled abdomen
19.6 mm	F	Dark and spiny. Food in gut. Fluid filled abdomen

Most individuals observed showed this enlarged abdomen. In some it was more obvious than in others. The possible association between water storage and skin modification during the dry season will be discussed below.

Juveniles

The proportion of juveniles in vegetation in the USW population is presented in Figure 3-15. The June peak in juveniles was mirrored in the Main Falls Spray Wetland, where juveniles made up 50% of the population (25 juveniles out of 50 spray toads recorded in the vegetation). The peak in juveniles followed the February peak in gravid females.

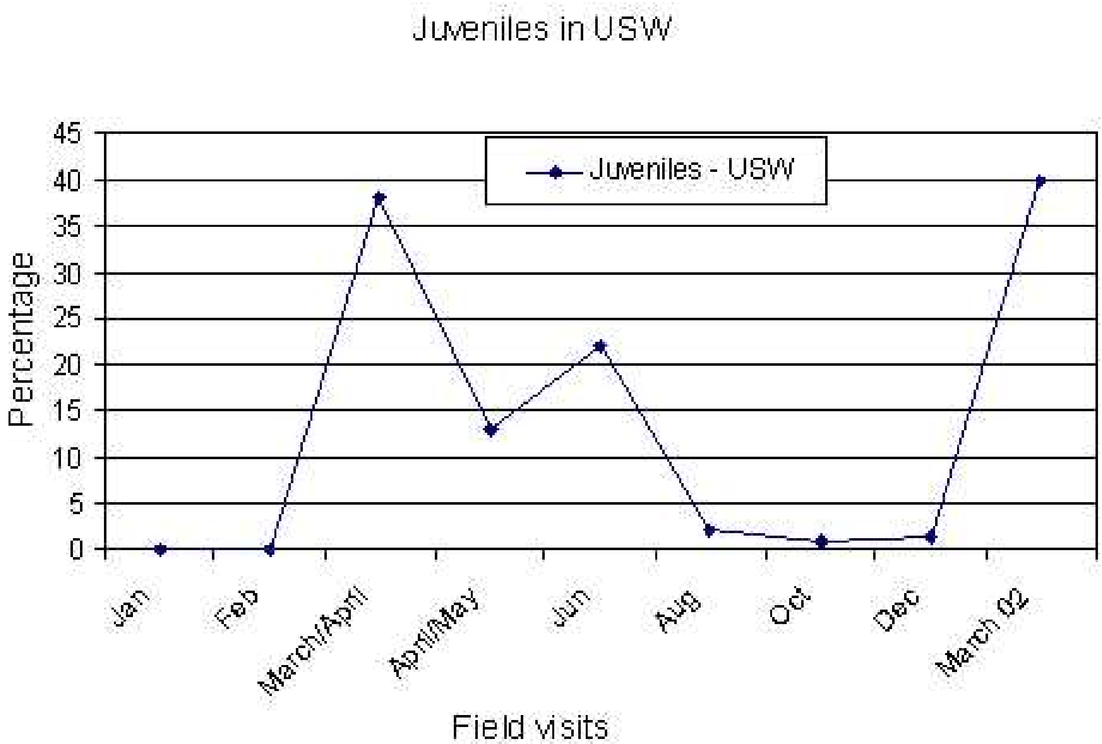


Figure 3-15	*The percentage of juveniles in vegetation in the population of the Upper Spray Wetland, 2001.*
Subadults	The percentage of subadults in the population of the USW is presented in Figure 3-16, and shows an increase in March and April with a peak in June. The June peak followed the March/April peak in juveniles.

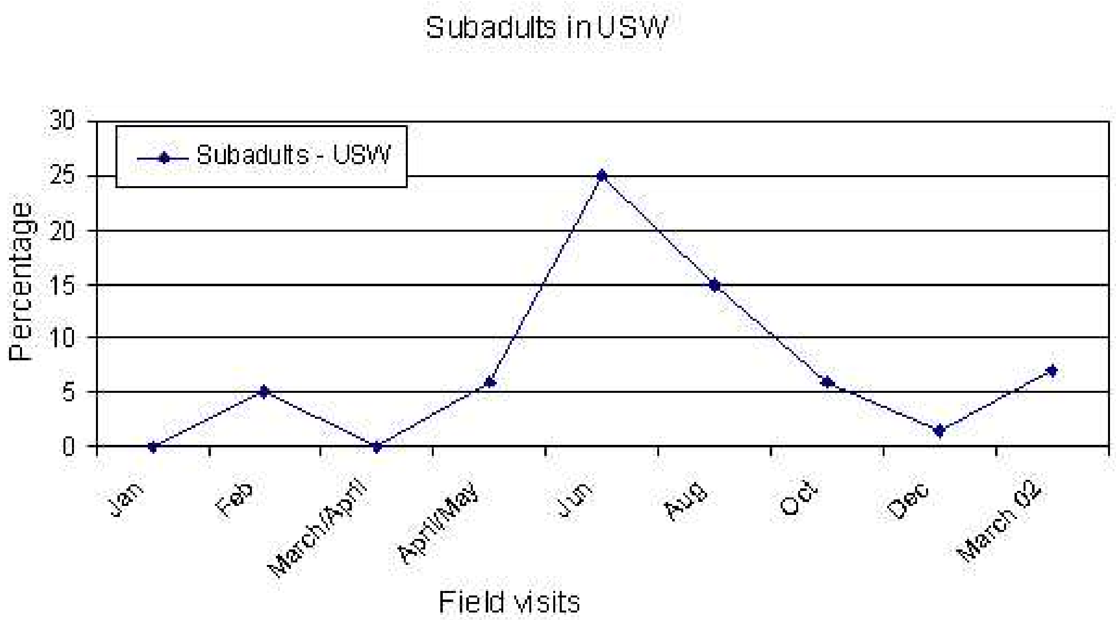


Figure 3-16	*The percentage of subadults in vegetation in the population of the Upper Spray Wetland, 2001.*
Other wetlands	During April/May the reproductive activity in the Mid-gorge Spray Wetland closely paralleled that in the USW. The data for the MGSW with the

USW in parentheses: Pairs in amplexus 1% (0%); females gravid 13% (12%); juveniles 26% (13%); subadults 16% (6%).

During the June visit 32% of spray toads found in the LSW were subadults (12 out of 38 spray toads seen during night observations). In the Main Falls Spray Wetland 30% were subadults (15 out of 50 found in vegetation transect). These results mirror the peak of subadults in the Upper Spray Wetland (25%).

Synchronous breeding

The synchronous breeding activity in wetlands with (USW, LSW, MGSW) and without sprinklers (MFSW) suggests that the artificial sprinklers are not a stimulus for breeding. In other amphibians rainfall, temperature, and daylength have been shown to be involved with seasonality of breeding (Duellman and Trueb, 1986). This indicates that the sprinklers improve the habitat quality without disrupting the breeding cycle of the spray toads.

3.5 Other amphibians

A number of amphibians have been recorded from the various wetlands or their immediate surroundings in the Kihansi Gorge. This list does not include the Gray Tree Frog (*Chiromantis xerampelina*), Fornasini's Spiny Reed Frog (*Afrixalus fornasinii*) or the Spotted Reed Frog (*Hyperolius puncticulatus*). One specimen of each of these three species was collected after materials for installing the sprinkler system in the USW and LSW were moved into the gorge. These specimens are regarded as accidental introductions. The other amphibians known from the Kihansi Gorge are listed in Table 3-9.

Table 3-9 Amphibians resident in the various Kihansi Gorge spray wetlands.

Common name - ***Scientific name* (Family)**	**USW**	**LSW**	**MGSW**	**MFSW**	**MSW**	**Notes**
Common Squeaker - *Arthroleptis stenodactylus* (Arthroleptidae)	X	X	X	X	X	Widespread in the Udzungwas, rare in the wetland.
Leaf Litter Frog - *Schoutedenella xenodactyla* (Arthroleptidae)	X	X	X	X	X	Present at ground level in wetland vegetation at high density in March.
Kihansi Spray Toad - *Nectophrynoides asperginis* (Bufonidae)	X	X	X	X	X	
Forest Dwarf Toad – *Nectophrynoides tornieri* (Bufonidae)	X	X	X	X	X	Present around and at the edge of the wetlands, also in areas receiving some spray.

Table 3 – 9 contd.

Common name - ***Scientific name*** **(Family)**	**USW**	**LSW**	**MGSW**	**MFSW**	**MSW**	**Notes**
Uluguru Tree Frog - *Leptopelis uluguruensis* (Hyperoliidae)		X				Found at the edge of the wetland, outside and just inside the sprinkled area.
Torrent Frog – *Arthroleptides* sp. (Arthroleptidae)	X	X	X	X	X	Present on wet rocks, and to some extent on the vegetation, mostly at night.
No. of species	5	6	5	5	5	

USW – Upper Spray Wetland, LSW – Lower Spray Wetland, MGSW – Mid-gorge Spray Wetland, MFSW – Main Falls Spray Wetland, MSW – Mhalala Spray Wetland

3.5.1 Torrent Frog

The Torrent Frog from the Udzungwas has been shown to be a species distinct from *A. martiensseni*. The description of the new species is in press. *Arthroleptides* sp. deposits eggs in large masses of around 200, or in smaller batches, on wet rock. The eggs develop into tadpoles that remain on the wet rock through development, only leaving when they metamorphose into juveniles. Eggs and tadpoles were present in January and March from the USW and LSW. Although the large *Arthroleptides* appears to feed on the forest floor and is found widely on the Udzungwa and Uluguru Mountains, it has a unique breeding system that places it in the wetland habitat where the Kihansi Spray Toad is found. Batches of eggs have been observed in the Upper and Lower Spray Wetlands and adults have been observed in all 5 spray wetlands.

This frog is most often seen at night in the Kihansi Spray Wetlands sometimes in high numbers on rock faces, and smaller individuals were sitting on leaves on top of the vegetation. They were also observed at night on the forest floor. The reproductive effort in this species is seasonal, and the breeding season appears to coincide with that of the Kihansi spray toad.

Figure 3-17 shows the average number of torrent frogs on New Frog Rock (plots A-E) compared to spray toads during the IREM project. Only night counts have been used. Except for the period early in the year when spilling over the LKHP dam probably made the rock habitat close to the base unusable the number of Torrent Frogs is very stable.

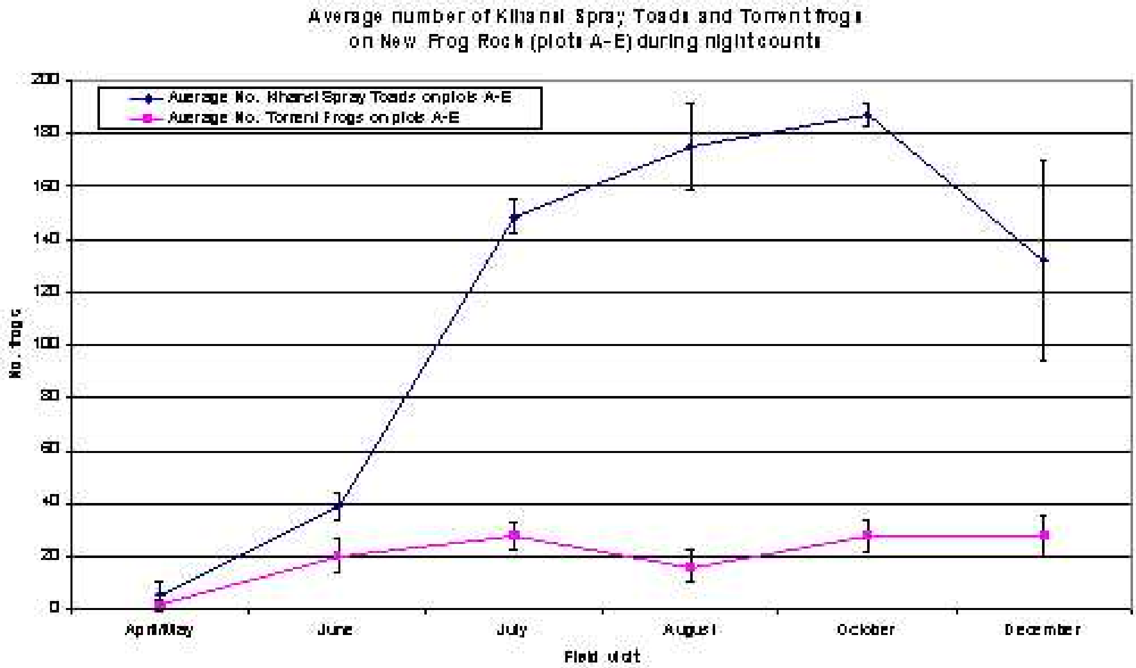


Figure 3-17 *Average number of Kihansi Spray Toads and torrent frogs on New Frog Rock (plots A-E) during night counts.*

The size of large females suggests that they are potential predators of the Kihansi Spray Toad.

3.5.2 Leaf Litter Frog

The small Leaf Litter Frog (*Schoutedenella xenodactyla*) is a direct developer. The eggs are laid at the base of vegetation under dead leaves, where they develop directly into small froglets without a free-swimming tadpole stage. During the March/April visit these frogs were present in the vegetation of the USW, where they forage at ground level. They were at high densities and might be competing for food with juvenile spray toads in the same microhabitat.

Competition

High numbers of Leaf Litter Frogs were only recorded during the March/April visit in the USW. During this visit the density of leaf litter frogs (12 in 22.5 m^2: population estimate 1 325, 95% CI 549-2 102) was slightly lower than that of spray toads in the vegetation (16 in 22.5 m^2: population estimate of 1 767, 95% CI 683-2 849). The Leaf Litter Frogs have a short breeding season and were never found at such relatively high density at any other time during the rest of the year. In March/April 2001 mean Leaf Litter Frog density was 0.13 per quadrat (0.25 m^2). In March 2002 the density was relatively high again (0.12 per quadrat, or 17 in 37 m^2). In March 2002 both species were recorded in the same plot. This suggests that although both species are present in the wetland, they are not direct competitors for food due to relatively low densities and the brief overlap of breeding seasons. Leaf Litter Frogs do not depend on the wetland for breeding, as they breed throughout the forest.

3.5.3 Common Squeaker

The common squeaker (*Arthroleptis stenodactylus*) is a widespread and common species in the forests of eastern and southern Africa. The wetland habitats are within the forest, and the record of this peripheral species may be due to an individual accidentally finding itself outside the forest proper.

3.5.4 Forest Dwarf Toad

This species (*Nectophrynoides tornieri*) has been uncommon in the Upper Spray Wetland, with only a few isolated sightings reported. During the August/September visit at least five individuals were found in the vegetation and on Old Frog Rock. Many individuals have been seen around both the Upper Spray Wetland and the Lower Spray Wetland. Perhaps this species makes use of the wetland habitat during the dry season while the forest floor is desiccated.

3.5.5 Uluguru Tree Frog

A small number of adults (*Leptopelis uluguruensis*) was seen at the southern boundary of the Lower Spray Wetland, and within the wetland. All were sitting on wet vegetation. This species has been reported intermittently from the Lower Spray Wetland since the beginning of the year, and has been seen in the forest south of the LSW.

3.6 Intermittent high flows

3.6.1 Wet season flow manipulations

Vegetation

Vegetation transects before, during and after the 9 consecutive days of flow manipulations did not show movement of the spray toads in the vegetation. Spray toads were found throughout the sprinkled area in the Upper Spray Wetland before, during and after the flow manipulations.

Rocks

Counts of New and Old Frog Rock were compared to check whether any movement in location of spray toads could be detected. Daytime (8:30 – 18:00) counts on New Frog Rock (NFR) and Old Frog Rock (OFR) before, during and after the flow manipulations are summarised in Table 3-10. 10 daytime counts were carried out before the days of high release, 14 (15 on OFR) during and 6 after the flow manipulations.

Table 3-10 Mean number of Kihansi Spray Toads counted during daytime on New and Old Frog Rocks in the Upper Spray Wetland before, during and after wet season flow manipulations (June 2001).

	New Frog Rock	**Old Frog Rock**
Before	29.1	18.2
During	13.5	25.4
After	27.7	38.5

These numbers indicate a movement away from the New Frog Rock during the days of high flow as winds became strong, with a subsequent movement back to the rock as the intermittent high flows ended. The immediate response to increased flow was also observable close to the falls. As soon as increased spray and wind were felt close to the falls, individual Kihansi Spray Toads could be observed moving away from the falls. The numbers are also an indication of a movement of spray toads towards the Old Frog Rock, possibly due to reduced rock habitat availability close to the falls, or as the Old Frog Rock became more suitable for the toads under increased spray generation. The high number of toads on Old Frog Rock after the flow manipulations may indicate that the effect is maintained shortly after manipulations cease.

As the flow increased on the first day of the flow manipulations (5th June) a rock face relatively close to the plunge pool of the upper part of the Main Falls was observed. Before the flow increase, a total of 48 spray toads were counted on the rock face. As the flow, wind, spray and sound from the falls increased dramatically between 11:25 and 11:30 (25 min delay from the start of the release at the dam site), the spray toads responded spontaneously. Usually the toads sit very still on the rock faces during the day, but now they started to move away from the plunge pool, wind and spray, either horizontally on the rock face or upwards to get on the leeward side. After 25-30 min with high flow there were 14 toads remaining on the rock face, of which all of them had moved to more sheltered area, for instance in crevices and behind small lumps on the rock face. After 4 hours of high flow there were still 12 spray toads present (75% reduction) in sheltered areas of the rock face. Just before the flow increase on the 6th, a total of 15 spray toads were seen on this rock face.

On a large rock face on the east side of the western arm of the upper part of the Main Falls a total of 169 spray toads were counted before the flow increase and just before the intermittent high flow started to be reduced a total of 84 spray toads could be seen (50% reduction). The increase in spray and wind was not comparable to the tremendous increase in the plunge pool. Also, this large rock face was along the river and not facing the falls. Just before the flow increase on the 6th, a total of 128 spray toads were seen on this rock face.

3.6.2 Dry season flow manipulations

Vegetation

Vegetation transects showed there was no population dispersal associated with the daily increase of flow bypass from 2 to 4 m^3/s during 5 consecutive days in August.

Rocks

The frogs aggregated on the west face of New Frog Rock were clearly aware of the increased flow, probably as the result of the increased windspeed and amount of spray blown onto the rocks. Many individuals were seen to adopt a ‘head-up’ stance as the spray increased, from the previous ‘tucked-in’ behaviour shown by the aggregating animals.

A response in the frogs on New Frog Rock was also apparent from the rock plot counts. Table 3-11 shows mean number of toads on New Frog Rock (NFR) and Old Frog Rock (OFR) before, during and after the flow manipulations. 5 daytime counts were carried out before the days of high release, 12 (13 on OFR) during and 4 after the flow manipulations.

Table 3-11 Mean number of Kihansi Spray Toads counted during day-time on New and Old Frog Rocks in the Upper Spray Wetland before, during and after dry season flow manipulations (August 2001).

	New Frog Rock	**Old Frog Rock**
Before	137.0	8.0
During	90.3	10.3
After	94.5	9.3

The numbers indicate a movement of spray toads away from the New Frog Rock during the flow manipulations. The difference in numbers of spray toads on Old Frog Rock is very small, and combined with the small sampling number it is difficult to interpret this as an increase in the utilisation of this rock as a result of the intermittent high flows.

Toads close to the river were not troubled by the increased flow, as they continued to forage, but did gradually move further from the river and the full force of the spray as the river flow increased.

It will only be possible to evaluate the effects of large bypass flows when it is possible to experimentally create conditions similar to that experienced before diversion.

Further details about the flow manipulations can be found in the Intermittent high flows and other specialist reports in Volume II of the IREM Final Report (NORPLAN, 2002a;b;f;g).

3.7 Sprinkler system

3.7.1 Upper Spray Wetland

The sprinkler nozzles installed in mid March 2001 appear to produce adequate fine spray that blows across the wetland, wetting the rocks and vegetation in a manner similar to that of the natural spray produced by the falls. The photographs in Appendix C show the Upper Spray Wetland with and without the sprinkler system installed. More details about the sprinkler systems can be obtained in the specialist report in Volume II of the Final IREM Report (NORPLAN, 2002d).

3.7.2 Lower Spray Wetland

The nozzles of the LSW were blocking frequently in January, and the southern-most (lowest) spray line was completely blocked, as the terminal valve was wide open but no water could be flushed out. The subsequent modifications to the sprinkler system, by the provision of a clean source from the Jabali Intake, and the provision of filters, has resulted in a more reliable and effective system.

3.7.3 Mid-gorge Spray Wetland

The sprinkler system in the Mid-gorge Spray Wetland was the first installed in the Kihansi Gorge. The system has been operating well and has been extended to cover almost all the spray wetland area. Due to the close surrounding forest the sprinkler in the Mid-gorge is more prone to damage by fallen trees as occurred in December 2001. The sprinkler was repaired and continues to function well.

3.8 Walkways

Upper Spray Wetland

The provision of stepping-stone walkways resulted in an immediate improvement in the wetland habitat, as trampling of the vegetation where the toads are found was significantly curtailed. Within days of construction the grass between the stepping stones was starting to re-grow in the areas receiving spray. Except for trampling along the walkways it appears that the construction of walkways did not make a significant negative impact on the Upper Spray Wetland, while the benefits are immediately apparent. The photographs in Appendix C show the path through the Upper Spray Wetland in July 2001 before the walkways were installed and in October 2001 after the walkways were installed.

Lower/Mid-gorge Spray Wetlands

Walkway construction in the Lower and Mid-gorge Spray Wetlands has also improved access and reduced habitat damage. Non-sprayed areas did not recover immediately after walkway construction but started to do so with the onset of the rainy season. However, these dry areas did not support spray toad population.

3.9 Skeletochronology

Most vertebrates living in seasonal habitats can be aged by looking at the structure of the long bones, such as the digits, or the arm or leg bones. During the dry season (or the cold season) the animal grows at a slower rate, and this is reflected in the bone structure by a line of arrested growth, or LAG. LAGs are also associated with seasonal breeding systems in tropical frogs (Kumbar and Pancharatna, 2001).

A typical section through a toe tip of a 28 mm female spray toad is illustrated in Figure 3-18.

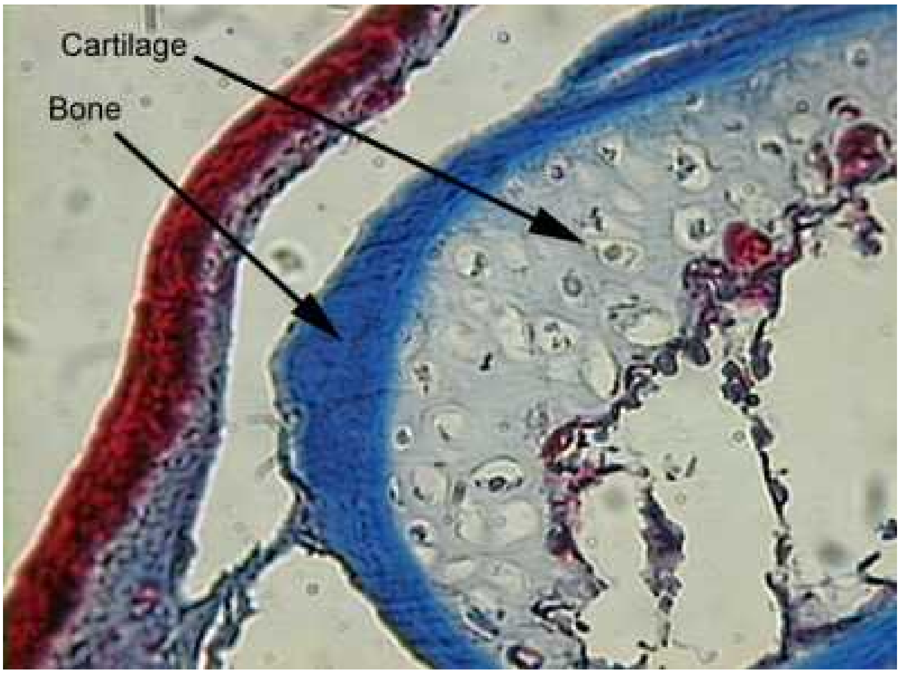


Figure 3-18 *A section through part of the bone of the toe tip of a 28 mm female spray toad collected in the Upper Spray Wetland.*

Neither the large 28 mm specimen nor the smaller 22 mm specimen examined showed any LAGs. There are two interpretations. Either the Kihansi Spray Toads live for less than two years, so that there is no time for a clear LAG to develop, or the habitat is so constant that the spray toads grow at a uniform rate through the year. See the discussion.

3.10 Skin structure

The dorsal skin of a Kihansi Spray Toad is remarkably thin, with a thin epidermis consisting of an outer *stratum corneum* a few cells thick, merging into the lower dermis with its granular glands and mucus glands overlying the smooth muscle layers (Figures 3-19 and 3-20).

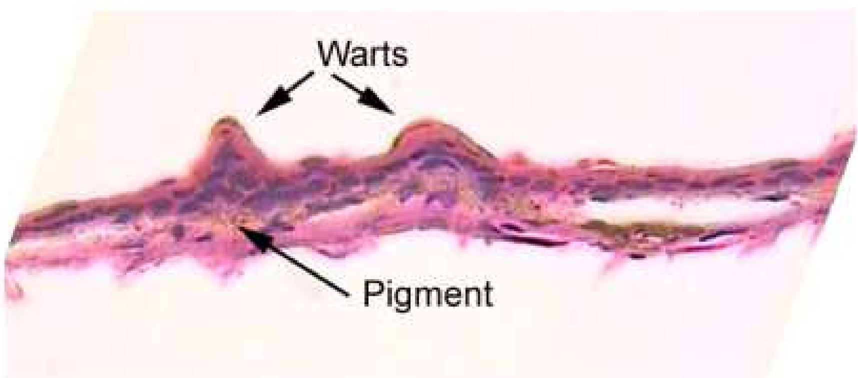


Figure 3-19 *Section through the dorsal skin of the male Kihansi Spray Toad.*

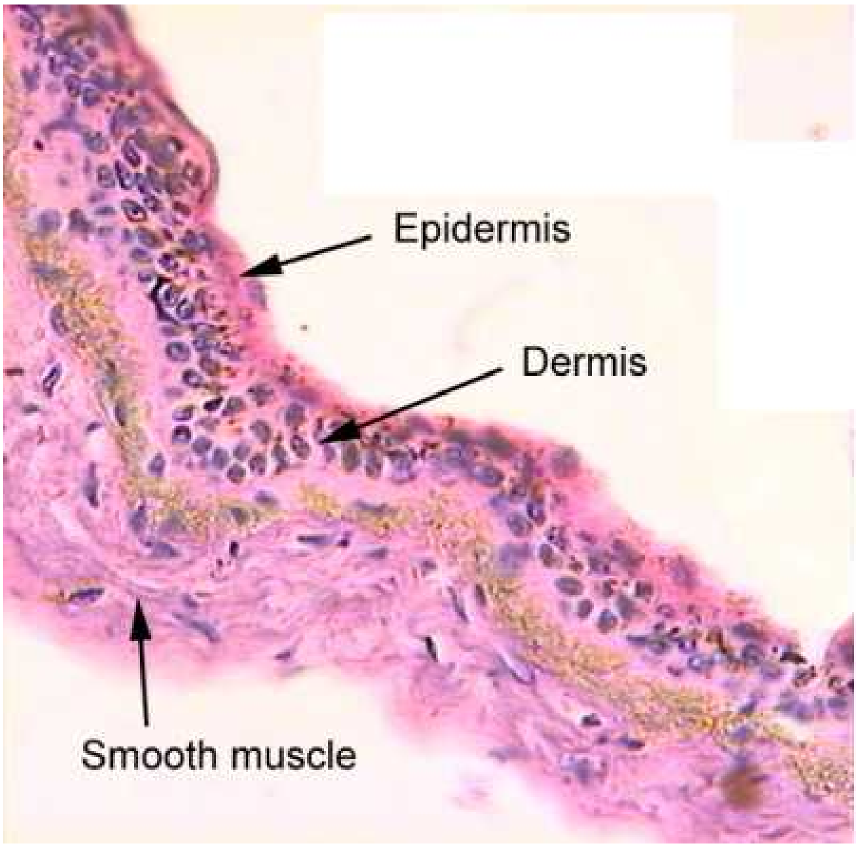


Figure 3-20 *Section through the dorsal skin of the male Kihansi Spray Toad.*

The small warts on the surface offer mechanical protection, while the granular glands secrete substances that make the toad unpalatable to predators. The skin is well supplied with blood vessels.

By comparison, the skin of a forest dwarf toad has twice as many warts, and has larger groups of granular glands.

3.11 General morphology

The Kihansi Spray Toad is one of the smaller members of the family Bufonidae. The largest adult females reach nearly 30 mm and weigh 0.8 to 0.9 g. Average body lengths are around 20 mm with weights of 0.3 g. The finger tips are rounded, and the toes are moderately webbed.

Colour change

Most of the Spray Toads observed during August did not show the bright yellow background with strongly contrasting brown markings that we have come to regard as typical for the species. Most were a dull, nearly uniform brown. The brown colour extends along the upper side of the limbs and covers the top of the two outer toes and fingers.

Associated with this colour change is a roughening of the skin with the accentuation of black-tipped spines along the limbs of some animals examined.

Hands and feet

The spray toads are able to climb vertical wet rock surfaces. They do this without adhesive discs on the fingers and toes. The feet are paddle-like with thick webbing between the toes that extends into a friction pad under the foot with only a trace of subarticular subercles. The fingers are slightly tapered without a distal swelling, but with a loose-skin friction pad on the palm without clear palmar or subarticular tubercles. The other species in this genus that climb have enlarged digital tips.

Illustrations to show the hand and foot morphology are presented in Figures 3-21 and 3-22.

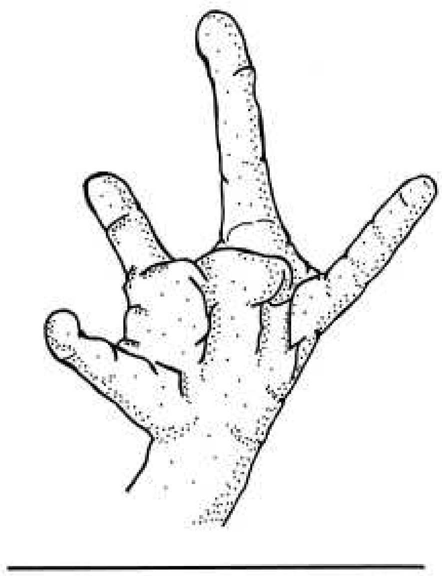


Figure 3-21 *The left hand of a Kihansi Spray Toad. Scale line = 5 mm.*

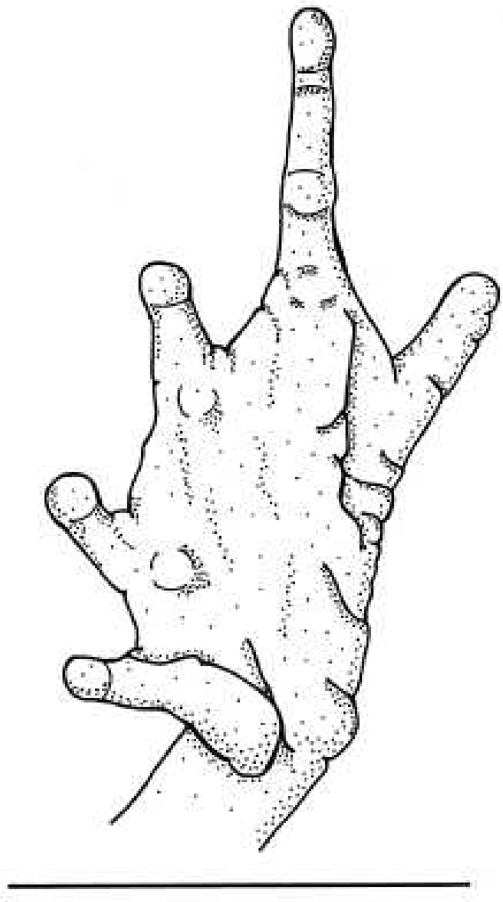


Figure 3-22 *The left foot of a Kihansi Spray Toad. Scale line = 5 mm.*

3.12 Food

Entomology report

Details of prey selection, prey availability, and prey distribution are available in the entomology specialist report in Volume II of the Final IREM Report (NORPLAN, 2002a).

3.13 Length and weight measurements

Length and weights were taken from live samples of sexed or unsexed specimens. Table 3-12 lists the available data.

Table 3-12 Available length and weight data based on living spray toads. Samples were taken from the Upper Spray Wetland (USW) and the Main Falls Spray Wetland (MFSW), 2001.

Field visit	Wetland	Males	Females	Unsexed	Notes
March/April	USW	Yes	Yes		Sampled from rock and vegetation
August	USW	Yes	Yes		Rock plot 4
August	MFSW			Yes	Plunge pool and side arm
October	USW			Yes	Rock plot 4
October	MFSW			Yes	Rock faces by plunge pool
December	USW			Yes	New Frog Rock
December	MFSW			Yes	Rock faces by plunge pool

Rock vs vegetation

The initial question posed concerned the animals found either on rock faces or on vegetation. Students t-test (2-tailed) showed that the lengths of toads from rock or vegetation were not significantly different ($p>0.10$, $t=2.1098$). Subsequent measurements were therefore made on animals collected from rock faces as these could be quickly collected, measured, and returned.

Male vs female

In the field the females appear to be larger than the males. This was investigated using lengths of samples measured from the USW. The two sexes were significantly different in length in April (t-test, $p<0.003$, $t=3.824$) and also in August (t-test, $p<0.00001$, $t=-8.188$).

Males April to August

The growth of males was tested by comparing the lengths of samples measured in April and August. The samples were significantly different (t-test, $p<0.05$, $t=-2.1249$). The mean length of the males in April was 16.7 mm, compared to 17.6 mm in August.

Females April-August

The females were also significantly different in length between April (mean 18.4 mm) and August (mean 21.8 mm). The t-test was highly significant ($p<0.000001$, $t=-6.9443$). The largest female measured was from the Main Falls Spray Wetland in August. This individual was 26.4 mm in length.

Unsexed April-August

In order to determine the growth trends for the whole USW population, a comparison was made of the lengths of unsexed spray toads between April and August. The difference was significant (t-test $p<0.008$, two-tailed). The mean April length was 17.7 mm compared to the mean in August of 19.1 mm.

Recruitment

The recruitment of subadults into the population by October leads to a smaller mean size. The mean length in August of 19.1 mm decreases to 15.6 mm in October. This is significant (two-tailed t-test, $p<0.00001$).

The growth of males and females in the USW through the year is illustrated in Figures 3-23 and 3-24.

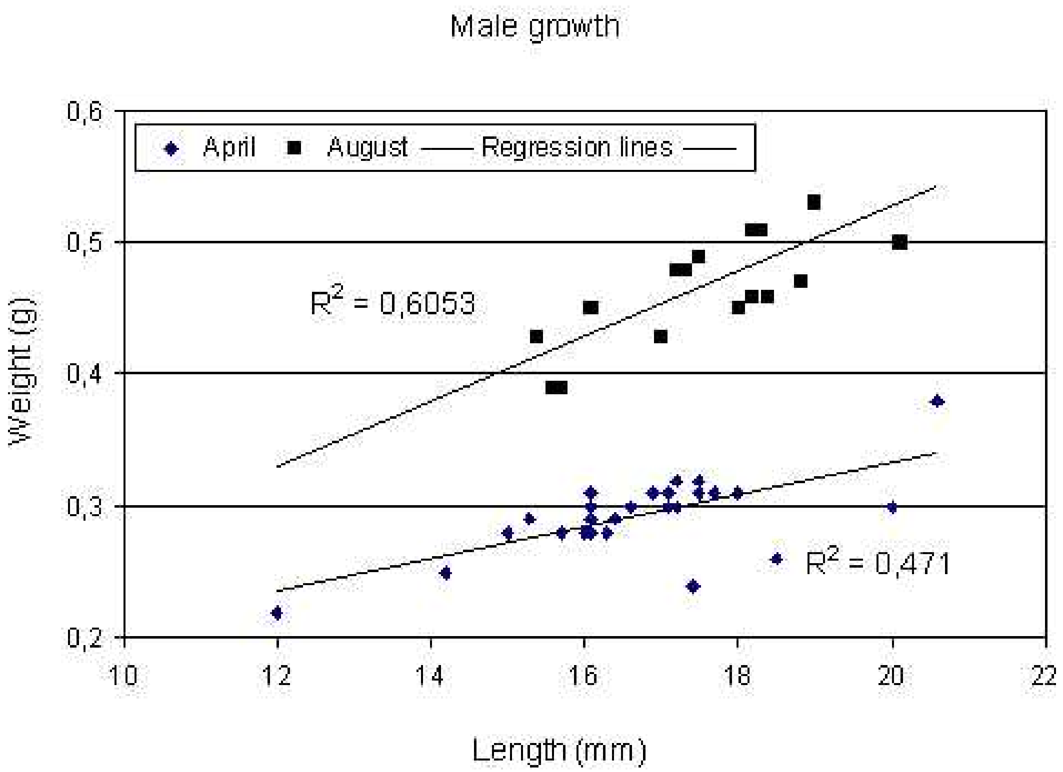


Figure 3-23 *Growth of male spray toads in the Upper Spray Wetland, 2001.*

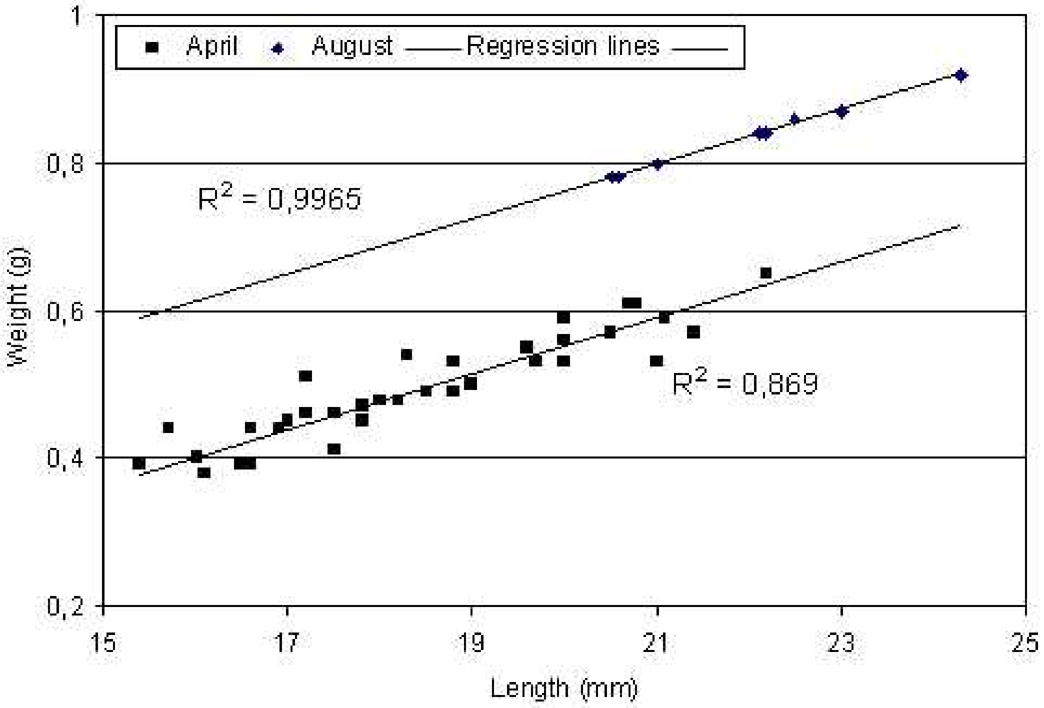


Figure 3-24 *Growth of female spray toads in the Upper Spray Wetland, 2001.*

3.14 General observations of toads and toad behaviour

3.14.1 Observations

Feeding

Feeding occurs on the top leaves of broad-leafed plants, within the vegetation in grass, or on wet rock. Feeding appears to occur both during day-time and night-time.

Strategies

The Kihansi Spray Toads adopt three main methods of foraging. The first is to sit and wait, becoming active only after a flying insect lands near them. The second strategy is to actively patrol on broad-leafed vegetation or wet rock surfaces, where they may lunge at adult insects or larvae wriggling in the water film. The third strategy is to stalk insects like flies. The flies allow the toad to get within 100 mm before moving. Samples of the flies have been collected and await identification.

There was continuous foraging by small numbers of frogs on spray-blown rocks, both during cool overcast times, and when the sun was out and the rocks were beginning to warm up. Frogs were seen to catch and eat white-winged insects (possibly Cicadellids).

Calling

Males appear to congregate and form choruses usually concealed in vegetation. Calling has been heard mostly during the day but with less calling after dark. A sound spectrogram of three advertisement calls is presented in Figure 3-27.

Amplexus

Amplexus seems to be most commonly seen on wet rock surfaces. The female presses her abdomen close to the substrate, and the male cloaca is closely adpressed to the female. Amplexus is prolonged, but no details of the duration have been recorded. Amplexus is axillary, with the male forearms clasped under the arms of the female.

Escape

Most toads on vertical rock faces were not disturbed by people passing nearby. Those that were would either climb upwards and shelter under overhanging vegetation, while others dropped off the rock to disappear in the vegetation below.

Aggregation

During the dry season large numbers of spray toads were found aggregating under overhangs on New Frog Rock, with the highest numbers on the west side facing the base of the falls from where the blown spray originates. This is illustrated by sample counts from New Frog Rock (mean=123, range 52-198, n=28).

These numbers are much higher than reported during the wet season in May, for example (mean=3, range 0-11, n=10).

3.14.2 Diel movement

The detailed counts of frogs onto permanent rock plot 4 are presented in Volume III of the Final IREM Report.

The diel movement results are presented graphically in Figures 3-25 and 3-26.

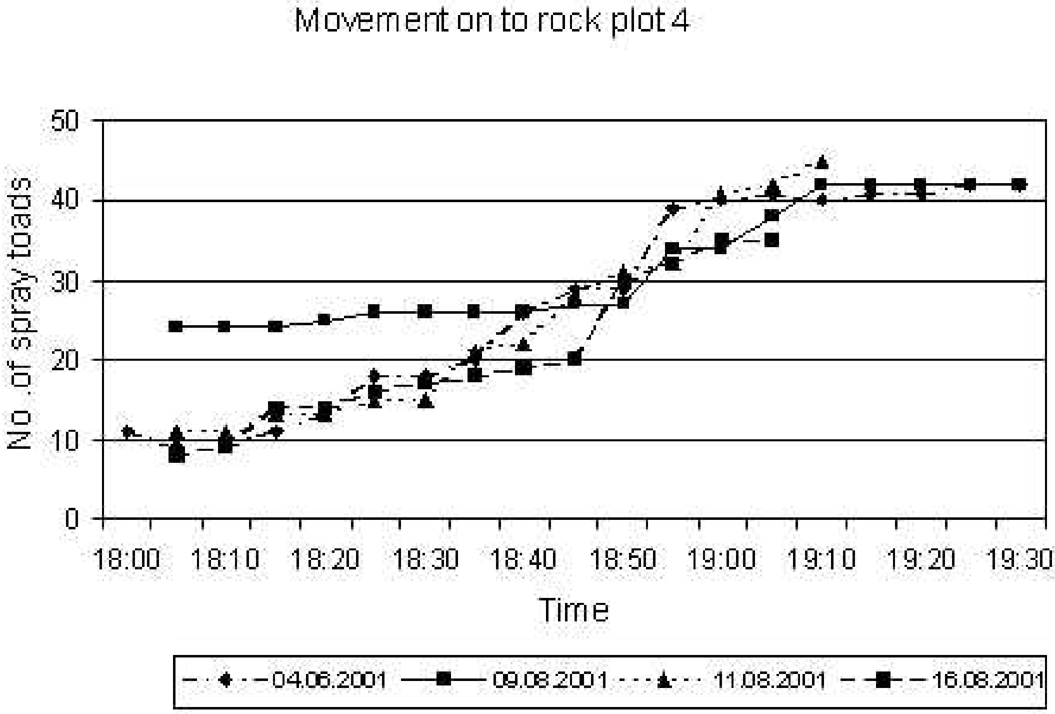


Figure 3-25 *Movement of toads on to rock plot 4 in the Upper Spray Wetland on four days.*

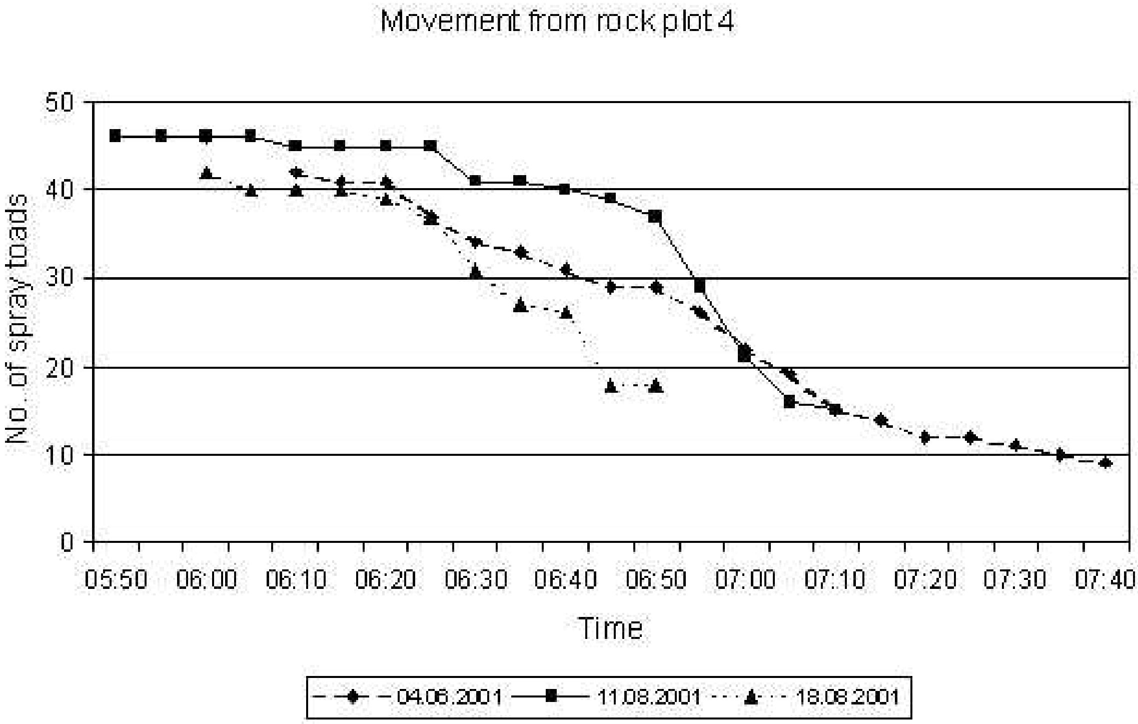


Figure 3-26 *Movement of toads from rock plot 4 in the Upper Spray Wetland. Data from three days.*

3.14.3 *Vocalisation*

Call types

Males vocalise, while the females are voiceless, as in most species of frog. Two common call types are heard in the wetlands; the first is the advertisement call, which is used to attract females. The second call is a male aggression call, used to space males. Each advertisement call consists of one to four pulses per note. The emphasised frequency is 4.2 to 4.4 kHz, and the pulses are produced at a rate of 167 per second.

The aggression call consists of a long series of notes, effectively a series of 'advertisement' calls strung together.

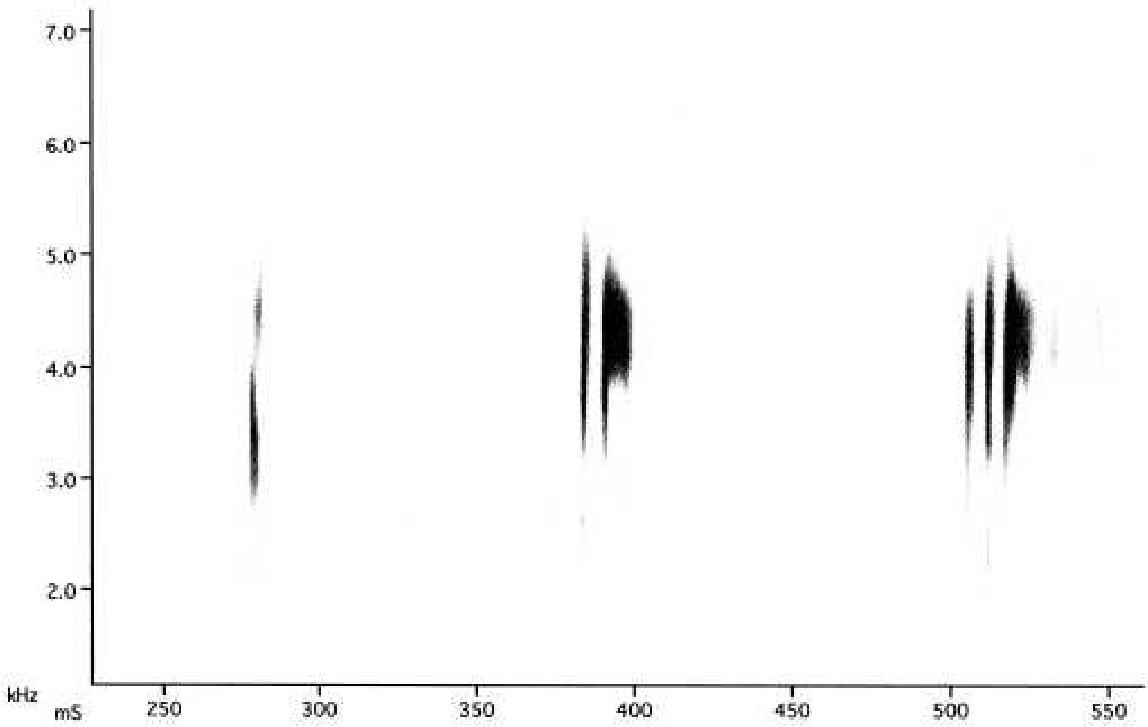


Figure 3-27 *Sound spectrogram of three advertisement calls of the Kihansi Spray Toad.*

3.14.4 *Predation*

Crab

Very few events of successful predation of Kihansi Spray Toads have been observed. A crab (*Potomonautes* sp.) was seen pulling an adult spray toad under a rock in a small stream in the Upper Spray Wetland. The crab had the right back leg of the toad in its claw while the spray toad tried to get away.

Amphibians

Torrent frogs, by their large size and close proximity to the spray toads, could represent a potential predator. However, despite the two species often being seen next to each other on the rock faces no events of predation or apparently attempted predation were observed.

Reptiles

Snakes have been observed in the Upper Spray Wetland during the day and at night on rocks and in the vegetation. They are potential predators of the Kihansi Spray Toad but no predation events were observed.

Insects

Until December none of the predatory safari ants (*Dorylus* sp.) had been observed inside the spray wetlands, although they had been observed at the periphery of the wetlands. During the December vegetation transects ants were observed in the Upper and Mid-gorge Spray Wetlands. In the Upper Spray Wetland they were observed at a number of different locations inside the sprayed area of the wetland on three consecutive days. Three Kihansi Spray Toads were observed being predated by ants in the Upper Spray Wetland.

Photograph 3-1 *Safari ants (*Dorylus* sp.) eating a Kihansi Spray Toad in the Upper Spray Wetland (December 2001).*

4 DISCUSSION

4.1 Population dynamics and population structure throughout the IREM project

Total gorge population

A best estimate of the total number of toads in the Kihansi Gorge was determined by summing the population estimates of the main spray wetlands. Combining the counts from the different wetlands is considered the most appropriate way of determining the number of animals in the Gorge, as techniques like mark-recapture could not be used on animals that do not move around and mix freely. The June, December and March 2002 estimates were used as these were high and statistically powerful as well and the October estimates, which covered all spray wetlands. These total estimates for the Gorge population are presented in Table 4-1, based on data presented earlier. The October 2000 estimates are taken from the World Bank report (World Bank, 2000b).

Table 4-1 Population estimates of spray toads in the Kihansi Gorge

	USW	LSW	MSW	MFSW	MGSW	Total Gorge Population estimate†
October 2000	10 865	763	96	470	14	12 200
June 2001	*5 241*	*296*	500*	5 812	*1 140***	13 000
October 2001	*7 618*	*323*	746	763	*1 703*	11 200
December 2001	*7 305*	*381*	500*	524	*1 415*	10 100
March 2002	*7 662*	-	500*	1 249	*2 462*	11 900

Numbers in italics indicate estimates in wetlands after sprinkler systems installed.
*The June allowance of 500 toads in the Mhalala Spray Wetland, and for animals peripheral to the main wetlands, is in line with observations made during the project.
** Using August estimate
† Rounded to nearest 100

October 1998

In October 1998, before diversion of the Kihansi River, an estimated density of 4.7 toads per m^2 in the vegetation of the Upper Spray Wetland was obtained (Howell *et al*., 1998). These data show that the spray toads were distributed across the entire Upper Spray Wetland, within a conservative estimate of area of 65 m x 66 m. On the basis of this it is estimated that the toad population in the Upper Spray Wetland could have been as large as 20 163 (4.7 x 65 x 66 = 20 163). The April/May 2001 Upper Spray Wetland core estimate of 1 258 suggests that the population of spray toads in this wetland reached a low point of around 6% of the pre-diversion estimate.

Estimate reliability

The size of the population in the USW has shown large changes through the year. This might be attributed to natural causes, i.e. the changes are real, or the difference in estimates might be due to observer bias in counting, or inadequate sample numbers. The latter was tested by means of a statistical power analysis (see Table 3-3). The estimates made during the IREM project are close to, or well above, the 50% precision level which is typical for similar ecological sampling (Krebs, 1999). This estimate is affected by the actual density of animals – with lower densities giving less powerful results (more chance of a type II error). Inspection of Table 3-3 shows that this holds for the IREM data.

Significant changes

Although the differences in population estimates in the Upper Spray Wetland during the IREM project from one field visit to the next were not always statistically significant, the decrease from February to a low point in March/April, and the subsequent recovery of the size of the population to October were significant (Table 3-2).

Negative factors

The factors that might cause toad populations to decrease include:

1) Reduced river flow due to diversion of water to the power station, producing reduced natural spray
2) Natural die-off of older individuals
3) Emigration due to drying of the habitat
4) Human disturbance from sprinkler construction activities and ecological sampling

Positive factors

The factors that might cause toad populations to increase include:

1) Increased natural spray from increased river flow when there is spilling from the dam
2) Spray from artificial sprinklers
3) Recruitment of juveniles into the population
4) Immigration from other areas
5) Improvement in local habitat quality in terms of vegetation cover and type, humidity and availability of food

Decrease to April

The USW population showed a large reduction of nearly 80% between January and late April. The reduction may have been partly associated with the reduced flow since diversion over the falls and with disturbance during the construction of the sprinkler system.

Increase to June

The increase in river flow in the rainy season was associated with an increase in the USW population from 1 752 in April/May to 5 241 in June.

Decrease to August

The population in the USW was observed to decrease again in August to 2 340. However, if the pulse of juveniles and subadults in the high estimate in June is discounted, then the adult population has, in fact, continued to increase. There is an increase from April to August, which is smoothed out if the recruitment peak of June is adjusted to adults only. The population has effectively increased from April to October.

Habitat use

The use of the habitat by the Kihansi Spray Toad appears to be determined by age, amount of spray and wind, and time of day. Juveniles are found only at ground level at the base of vegetation where there are plenty of small food items. Adults forage on wet rock faces, on top of the vegetation, or in the three-dimensional habitat within the vegetation. Toads are found where the habitat is wet from spray. In periods of very high river flow, when the spray is driven by strong winds from the base of the falls, the toads avoid the areas of strong wind. When it is hot or dry the toads are often concealed in the vegetation or in the shade of a rock.

Core area

The core area concept permits estimates to be made of the size of a population that appears to be moving as seasonal variations in the conditions in the wetlands occur. The core area as used by the spray toads is dynamic. They appear to be selecting wet areas without excessive wind energy. It is remarkable that they are able to respond relatively rapidly to changes in spray patterns caused by differences in river flow rate, and suggests that this may be one of the reasons for their continued success in this habitat.

The apparent 50% decrease in the population of the Upper Spray Wetland from June to August might reflect a movement out of the wetland vegetation, possibly to the rocky habitat along the river, or may reflect the natural mortality of older individuals after the breeding.

Migration

The observations over the year indicate that many toads have home ranges, as particular individuals can be seen feeding in exactly the same place over a number of days. On the other hand, the toads are able to move rapidly when conditions are cool and wet, and there are no permanent barriers to migration throughout the gorge. The Kihansi River itself can be crossed. The fact that there are spray toad populations at various locations along the Kihansi River and on both sides of the river indicates that migration occurs and that there probably is genetically significant exchange of individuals between the populations.

The apparently stable population of toads in the gorge as a whole, despite the significant differences between field visits of the USW estimates, suggests that large-scale movement may be occurring. The most likely routes would be along the rocks bordering the river. The movement appears to be upstream towards the main falls in hot dry weather (during hot dry weather from June to October a dramatic decrease around the main falls) and downstream in wet weather with increased river flow. This hypothesis could be tested during the long-term monitoring. This must be seen as a hypothesis, based on counts in the USW.

Mitigation

The fact that there is an apparently stable overall population in the Gorge despite relatively large fluctuations can also be alternatively explained by the implementation of mitigation measures. The Mid-gorge and Lower Spray Wetlands, which both had sprinklers installed throughout the entire IREM project showed relatively little variation. The Upper Spray Wetland following installation of the sprinkler showed an overall increase in population. Much of the variation in the overall Gorge population is attributed to the change in the population in the Main Falls Spray Wetland. The population in the Main Falls Spray Wetland declined dramatically during the dry season of 2001. This wetland is dependent on the bypass flow for spray generation and thus the area of available habitat reduced during the dry season once spilling stopped and the flow was only the 1.5 – 1.9 m^3/s bypass flow. It is thus suggested that the implementation of mitigation measures in the Kihansi Gorge could explain the variation in spray toad population observed in the different wetlands.

Critical factors

The Kihansi Spray Toad is an example of an extreme specialist. The thin skin restricts the toad to cool, humid areas, while the small size and climbing ability allow it to live on the rock faces within the direct spray zone of the various falls. Food appears to be mostly small insects that themselves feed on the vegetation in the wetland. It appears that much of the natural behaviour (probably including reproductive behaviour such as sexual selection) takes place within spray wetland vegetation and on wet rock faces.

In order to maintain a permanent population under natural conditions, the habitat must provide abundant food in the form of small insects, shelter and very small insects for the juveniles, and high humidity. The structure of the habitat should include wet and low growing vegetation (e.g. grasses, small herbs and the club moss *Selaginella kraussiana*) and wet rock faces.

Longevity

The age of breeding adults has implications for the time taken for population numbers to recover after a severe reduction, such as happened in the Kihansi Gorge after diversion. Short-lived species will be better able to recover numbers in a short time, although longer-lived species may be able to better cope with prolonged adverse conditions. The strategy used by any species is selected for over long periods of evolution/natural selection.

The age of a large 28 mm adult was estimated at less than two years, as no annual growth ring was present in the bone structure. As breeding is seasonal, we would expect seasonal differences in nutritional status that reflect in the structure of the bones. Even tropical species living in nearly uniform environments display this structure (Kumbar and Pancharatna, 2001).

Related species

A related West African species, (*Nimbaphrynoides occidentalis*) reaches 5 years in females and at least 2 years in males, based on bone rings. During the first period of hibernation the frogs resorb the inner part (endosteum) of the long bones, during a period of low metabolism (Castanet *et al*., 2000).

4.2 Reproductive cycle of the Kihansi Spray Toad

The Kihansi Spray Toad is ovoviviparous: fertilisation is internal, and the tadpoles are retained within the oviducts where they develop into small frogs before they are born. Clutch size varies from around 5 – 13. Breeding is strongly seasonal, with peaks in amplexus from December to February, with a peak in juveniles in March, and a corresponding peak in subadults in June to August. The population appears to consist almost solely of adults in December, January and February.

Vocalisation

The males produce two types of calls: a single peeping advertisement call that serves to attract females, and a male spacing call that males use to define their breeding station. Male advertisement calls have been heard both during the day and night from within vegetation. The male spacing (territorial) call is produced when one male moves close to a second male and has been heard both from vegetation and rock faces.

Seasonality

The Kihansi Spray Toad displays seasonal breeding. The proportion of pairs in amplexus was high in January 2001 (and presumably in December 2000). During January and February there is a peak in gravid females, followed by a high percentage of juveniles in March through to May. Sub-adults reached a peak in May, June and July. During August there was a large proportion of small adults and large subadults, suggesting that the new generation made up a substantial fraction of the population.

The presence of juveniles through the wet season (March to June) in the USW, was also observed in the Main Falls Spray Wetland. This supports the suggestion (Poynton *et al.*, 1998) that the breeding season is extended. Questions that arise are:

1) Are there two annual breeding stimuli, initiated at the start of the short and long rains?
2) Is the extended breeding season the result of some females being ready to breed before others, without stimuli related to spray from the sprinkler system or rainfall?

These questions could be investigated as part of future activities in Kihansi.

4.3 Other Ecological aspects of the Kihansi Spray Toad

Distribution

The Kihansi Spray Toad has only been found in wetlands along the rivers in the Kihansi Gorge. The toad is absent from the nearby Udagaji and other gorges, despite day and night-time searches by different groups over the last four years.

Habitat use

This species is restricted to areas with spray and resulting high humidity. These conditions prevail in the relatively open wetlands, but not in the surrounding forest. Within the spray wetlands the species is found on vegetation and wet rock faces.

Vegetation

Like other amphibians studied, this toad appears to be associated with wetland plants, rather than with particular plant species. Common plants that are used by the toads in the wetlands include *Selaginella kraussiana, Leersia hexandra, Pilea rivularis, Impatiens digitata* and *Brillantaisia madagascariensis.* The Spray Toad prefers wet vegetation, although they have been seen foraging for insects on dry leaves. Adults will forage on top, or within the vegetation. The lower levels of the vegetation, where there is leaf litter and growing roots, serve as the nursery areas for the juvenile toads. Juveniles, subadults and adults are all found in the vegetation.

Rock

The Spray Toads are found on sloping rock faces where the water from the spray drains. They are able to climb on vertical wet rock faces, and easily climb wet rock overhangs. Rock faces are used mostly by adults, and some subadults, but no juveniles have been recorded on such rock faces. The pad-like structure of the webbing of the foot and the palm of the hand enables the toads to move over vertical wet surfaces. The toad has great difficulties climbing vertical dry rock faces.

Aggregation

Large numbers of spray toads were counted aggregated in shaded overhangs on New Frog Rock, and foraging on the rocks at the base of the Upper Falls during the dry season. The mean number of aggregating frogs outside the rock plots (one count for each of ten days) was 106. An estimated 150 frogs were seen foraging on the rocks around the base of the falls on cool days. The aggregating behaviour was not seen during the wet season.

River level

Changes in river flow result in changes in spray quantity, wind strength and river level. The toads move quickly to remain above water level, in areas receiving spray. They avoid areas of strong wind where the spray is blowing horizontally. Strong winds from the base of the falls have been seen to blow adults across the rock face.

Predators

The only two positive records of predation on a spray toad are by the river crab *Potomonautes* sp. and safari ant *Dorylus* sp. Potential predators known from the wetlands include the bush snake *Philothamnus* sp., and the torrent frog *Arthroleptides* sp.

Water storage

The slightly expanded abdomens of many toads in the wetland during the dry season, males and females, appears to be due entirely to fluid, probably water stored in the bladder (Table 3-8). Even a few females with embryos had nothing but fluid in the posterior abdomen. This kind of "pseudo-gravid" state was not recorded earlier in the year.

Most of the adults observed in August showed a darkening of the skin, associated with a roughening and the development of small dark-tipped spines, visible with a lens. The roughening of the skin approaches the condition of the integument in terrestrial bufonids, such as *Necto-phrynoides tornieri* from the adjoining forest. In these and similar species the thicker glandular skin serves as a water-conservation mechanism. The associated increase in body fluid in the abdomen suggests that this species has a water conservation strategy in the dry season. This strategy is also known from other amphibians.

Seasonality

There appears to be a distinct seasonality in the biology of the Spray Toad. The evidence below suggests that it is a dry-season vs wet-season response, but when more data are available it might prove to be more complex. Note that the following were observed even though the sprinkler system was maintaining a very wet, insect-rich vegetation throughout the wetland. See Table 4-2.

Table 4-2 *Comparison of some characteristics of the Kihansi Spray Toad in the wet and dry season.*

Characteristics	Wet season	Dry season
Coloration	Most animals bright yellow	Most animals dull brown
Skin	Skin smooth	Skin rough
Distribution	Population throughout wetland. No significant dispersal along river rocks	Population closer to base of falls. Large numbers aggregate on rocks near river
Population structure	Many females gravid. No juveniles or subadults early in wet season, boom in juveniles at end of wet season.	Very few females gravid. Boom in subadults that enter adult stage quickly.
Reproductive behaviour	Vocalisations heard throughout day and night. Many pairs in amplexus.	Few vocalisations. Few pairs in amplexus.

Pathology

Evidence of disease in the Kihansi spray wetlands was not observed during field visits. The 500 adults transported to the USA for captive breeding were affected by lungworm suggesting that this is present in the spray wetlands (Lee, 2001). However, none of the small number of specimens dissected for the IREM studies showed any evidence of disease or high lung parasite load.

All animals naturally have nematodes in the gut. Counts of these were made during the entomology studies of spray toad diet (See Volume III - Final Specialist Report: Entomological studies (NORPLAN, 2002a)).

In nature, animals that are diseased will quickly lose condition and die. Even if this were happening in the wetland on a small scale there is little chance that these animals would be sampled. Large-scale disease would become obvious, but no such observations have been made this year.

4.4 Other amphibians

The Udzungwa Mountains of Tanzania are recorded to have 29 species of amphibians (Channing, 2000). Within the Kihansi Gorge there is a surprising lack of amphibian diversity. Only six species occur naturally in the gorge, and there are single or a few records of a further three, attributed to accidental introductions. The Kihansi Spray Toad is found nowhere else. This is additional evidence for the unique and special nature of this habitat. The high spray load in the gorge must have been present and relatively reliable for a very long time in order for the Kihansi Spray Toad to have evolved.

Other declines

The decline noted in the population estimates for the spray toad through the first half of the year is paralleled by the decline in the number of leaf litter frogs counted in the vegetation. This is evidence that the toad decline is probably not a phenomenon restricted to the spray toads, but reflects a change in the habitat. However, the extent to which this was a natural phenomenon or was caused, at least partially, by human disturbance is not known.

4.5 Effect of intermittent high flows

The following comments are based on the results of two series of flow manipulations: One took place just after a period of relatively high flow, and the other during the dry season with low flows. The first was following a time of high spray when the extra flow made little difference to an already wet habitat. The flow through the gorge the two weeks before the wet season flow manipulations varied between 1.9 and 14 m^3/s, with an average the 10 days before of 3.7 m^3/s. The day before the flow manipulation started there was a 4 hour period of flow around 5 – 5.5 m^3/s due to spilling from the dam.

The second manipulations took place during a very dry time when only a slight increase to 4 m^3/s for 2 hours in flow was possible. The flow through the gorge the two weeks before the flow manipulation was 1.9 – 2.0 m^3/s.

Vegetation

There was no change in the distribution of Kihansi Spray Toads across the Upper Spray Wetland vegetation related to intermittent flow manipulations. The toads do expand the core area when there is more long-term spray, such as during the rainy season when the river has a high flow for months. In order for intermittent flows to be effective they would have to happen on a regular daily basis.

Two transects were counted in August, positioned at the edge of the core area determined before the flow manipulations. One line ran north to south at the level of the top of line 4, below Old Frog Rock. The other ran west to east between sprinkler lines 16 and 17. A total of 43 quadrats (17+26) yielded one subadult. During the pre-manipulation count one spray toad was counted in the same area.

This indicates that the increased flow of 4 m^3/s for 2 hours per day for five days, did not result in any expansion of the spray toad population into the vegetation further away from the falls.

In areas with an established and functioning sprinkler system, the IREM studies showed no evidence that the toads move into newly sprayed vegetation once the increased flow is initiated. Likewise, the toads do not move after the increased flow is terminated. It appears that toad movement is related to long-term changes in the habitat.

Different flow regimes, other pre-testing bypass flows and non-sprinkled areas could show different results. General observations over three days in June 2000 (before sprinkler installation) during intermittent high flows indicated an effect of the intermittent high flows. Prior to the intermittent high flows the entire spray toad population in the Lower Spray Wetland appeared to be sitting clustered close to the Kihansi River. After initiation of intermittent high flows (4 hours of 8 m^3/s per day) the number of toads close to the river was reduced and the number of toads in the vegetation as well as the distance from the falls they were found increased for each of the three days general observations were made.

Rock

The intermittent high flows do not pose a threat to toads foraging on rocks at the edge of the river. The river flow builds up relatively quickly with an increase in noise and spray. The toads move quickly away as experienced during the increase from 2 to 8 m^3/s or continue to forage in the spray close to the water before moving higher up the rocks as seen during the increase from 2 to 4 m^3/s in August. Observations from the foot of the falls by the Lower Spray Wetland in June 2000 support this view. A few toads sitting on a rock in the river were washed away, while the remainder quickly walked towards sheltered area once the flow increased.

The population estimates show that the core area of the toads expands into the wetland when there is a permanent high spray volume. However, the population estimates of the spray toad were constant before, during and after the experimental intermittent flows.

Flow manipulations do not appear to have any effect on feeding behaviour, although long-term changes allow the toads to expand into the vegetation where there are prey insects. We have seen no evidence that reproductive behaviour or day/night activities change.

2 hrs/4 m^3/s

Short daily periods (2 hours) of 4 m^3/s bypass flow have no effect on the distribution of toads in the wetland, although the animals appear more alert in the zone of increased spray, as those clustered on New Frog Rock lifted their heads and became active shortly after the flow manipulations started.

Spray vs. flow

In general there is not likely to be a linear relationship between spray generation and river flow. A doubling of river flow will increase spray generation more than twice, and a reduction to half the flow will more than halve the spray generation. This has been shown both in Kihansi and elsewhere (Odland, 1990, Odland *et al*., 1991). Further, the change in spray generation is dependent upon the topography in the river, e.g. which rocks in the river and how does the water hit these rocks with varying flows. For instance, in the Lower Spray Wetland there is a large rock by the foot of the falls that the water starts hitting at around 6-8 m^3/s, after which spray generation increases tremendously. Intermittent high flows of 4 m^3/s will have limited effect in the Lower Spray Wetland. Details about the relationship between flow and spray generation in the various spray wetlands need longer periods of intermittent high flows to be studied, if deemed necessary.

4.6 Effect of the sprinkler system

Vegetation

The grassy vegetation used by the spray toad has started to return to its pre-diversion state since the sprinkler system was installed. See the Final Specialist Report: Vegetation Studies (Volume II of the Final IREM Report) for details (NORPLAN, 2002b).

Prey

Both the indicator prey species, *Afrosteles distans* and *Ortheziola* sp. had by July showed a significant increase in numbers since the sprinkler system was installed. It appears likely that if the wetland is not allowed to dry out to the extent that it did in late 2000, both species should be capable of a substantial and sustained recovery (NORPLAN, 2002a).

Non-sprinkled area

The presence of significant numbers of spray toads seen and heard outside the sprinkler area only during the wet season suggests that the increased flow over the falls during this rainy season produced conditions within the wetland that have enabled the toads to spread. The sprinkler system remains critical to the wetland under conditions of reduced river flow over the falls. The sprinkler system (or some other long-term method to wet the area) should be able to produce a dry-season reserve, from which the toads can move when natural spray increases in the wet season.

The wetland habitat under the sprinkler system closely resembles the certain physical conditions before diversion. The vegetation is recovering, but it will still take some time for the soil structure and the vegetation covering the rock faces to return to its previous state. High wind speeds generated by natural flows in the Kihansi River are currently not reproduced. Consequently taller plants, and to some extent different species are expected to cover the spray wetlands as long as water is diverted to the power station. A change in plant species composition is, in itself, not necessarily a problem for the survival of the spray toad. Differences in vegetation composition between the wetlands and the fact that the spray toad does not appear dependent on specific individual species illustrate this.

Without the sprinkler system the available toad habitat would be reduced to the edge of the river. Along the river there is little vegetation to support the insects that the toad requires for food and the vegetation required for the juveniles is very limited. The sprinkler system (or some other system of wetting the habitat) appears to be essential for the long-term maintenance of the populations of this critically endangered toad.

4.7 Effect of walkways

The stepping-stone construction allows the vegetation to grow and permits surface drainage to take place naturally. After a short-term negative impact along the walkways due to construction activities, the major and longer-term impact has been the reduction in habitat trampling. The juveniles use the vegetation as a nursery area, and the adults breed and feed within the vegetation. The walkways are an essential feature of the mitigation effort.

4.8 Impact of LKHP

The Lower Kihansi Hydropower Project has, paradoxically, both negative and positive influences.

Focusing only on the Kihansi Spray Toad the obvious negative influence has been the loss of much of the area of suitable habitat caused by the dramatic reduction in flow over the falls.

The positive influence has been that the Kihansi Spray Toad, is at once the most critically endangered amphibian in Africa and also one of the better studied.

If a low-maintenance system can be provided to effectively deliver spray to the wetlands over the long term, then the negative impact of the LKHP will have been reduced on the ecology of the unique habitat of the Kihansi Spray Toad. During the short-term Immediate Rescue and Emergency Measures project it has been possible to study certain short-term impacts of the LKHP and the implemented mitigation measures. Continued monitoring will be needed to identify longer-term and possibly unexpected impacts.

4.9 Conservation strategies/implications

Population estimates

Management strategies for the Kihansi Spray Toad will depend on reliable population estimates. Data collected during the IREM project showed that it is important to base population estimates on counts made at the same time of day. The diel behaviour pattern involves the toads being more visible after dark when they move on to the top of vegetation and on to exposed rock faces. It is likely to be difficult to carry out vegetation transects at night. Day-time counts should be supplemented with at least limited night counts.

Fragile habitat

The need to understand the ecology of the species is important to ensure its long-term survival, either naturally or in an artificially mitigated situation. However, when faced with a species that is critically endangered, compromises will need to be reached to balance the statistical needs of scientists, and the impact that vegetation trampling as well as risks of disease and parasite introductions might have on the toad. Perhaps vegetation trampling has a minimal effect on the toad population but it is highly risky assuming that this is so. It is suggested that a protocol of minimal disturbance should be initiated, and even minimal data gathering if necessary, at least until it can be shown that the toad population has increased and is stable. If it should decline to extinction, then all the appropriate data will be of only academic interest.

Index of abundance

The mean daytime counts on the 13 permanent rock plots correlate significantly with the vegetation estimates (Power regression r^2=0.6302, See section 3.2) This implies that future management strategies can use simple rock counts for determining trends in the spray toad population in the USW.

4.10 Searches/translocation

Searches

The Kihansi Spray Toad has not been found outside the Kihansi Gorge. The species' status as critically endangered remains. Details about the searches carried out in the Udzungwa Mountains are presented in the Final Specialist Report: Searches/translocation (NORPLAN, 2002e).

Other members of the genus *Nectophrynoides* also have very restricted ranges, for instance *N. wendyae* known only from an area above Chita, and four out of six species are known only from the Udzungwa and Uluguru Mountains. Considering the restricted range of the genus and its species, combined with the extremely specific habitat requirements of the spray toad, it is not considered likely that the spray toad will be found outside the Kihansi Gorge. Day and night searches in the closest and probably the habitats with the highest likelihood of supporting the species (that is, the Upper and Lower Lufulutonya and Udagaji Gorge Spray Wetlands) did not result in observations of the Kihansi Spray Toad. These locations are close, and theoretically reachable for the spray toad given certain conditions. Also, the Upper and Lower Lufulutonya Spray Wetlands are along the Kihansi River, only some 3-4 km upstream of the gorge and experience more or less the same hydrological regime as the Kihansi Gorge itself, including high and stable dry season flows.

Translocation

Spray wetlands comparable to the Kihansi Gorge Spray Wetlands in terms of extent and spray deposition were not found during the IREM studies. Some small areas of spray wetland were found although further studies would be required to determine whether they are suitable translocation sites. The success rates of amphibian introductions are not particularly high and are often dependent on a thorough understanding of both the species being introduced and the site it is being introduced to.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Status of the Kihansi Spray Toad in the Kihansi Gorge

The population of spray toads has recovered somewhat after the sprinkler systems were installed. The drastic loss of habitat has been mitigated by the sprinklers.

For the moment the populations throughout the Kihansi Gorge are no longer decreasing. The fluctuations seen this year may partly represent natural cycles in population numbers.

5.2 Future of the Kihansi Spray Toad in the Kihansi Gorge

For the Kihansi Spray Toad to survive *in situ*, in the Kihansi Gorge, it is necessary for the spray wetland habitat to be maintained.

Minimally this would mean providing adequate moisture input into the spray wetlands at levels associated with a pre-diversion dry season average of around 7 m^3/s. This is equivalent to a precipitation of around 80 000 mm/year.

The spray toad population is thought to have suffered a major decline following diversion of the Kihansi River and it is not known what the minimum viable population of the species is. The IREM project has been a short term, emergency project. Further monitoring of the population will be required in order to investigate whether the species can make a long-term recovery.

5.3 Artificial sprinkler

The sprinkler system maintains a film of water droplets on the vegetation that resembled the pre-diversion conditions. Spray from the sprinkler nozzles also maintains a relatively stable and high humidity and low temperature. The vegetation appears to be recovering after a serious drying out during the dry season of 2000, and appears to provide good quality habitat despite some changes in plant species composition and physiognomy. The sprinkler may prove to be essential in recreating and maintaining water logged soils in the wetland.

The increase in the toad population and its distribution across the wetland since the sprinklers were installed indicates that this mitigation measure is having a positive effect. A well operated and maintained sprinkler system appears to support the Kihansi Spray Toad population. Whether any long-term changes in the spray wetland ecosystem will affect this situation is uncertain.

5.4 Walkways

The walkways of stepping stones made a major improvement in the habitat within the first few days of their installation. The mechanical damage to the soil and vegetation is minimised, while access is faster and less hazardous for sprinkler maintenance and biophysical monitoring.

5.5 Intermittent high flows

There was no discernible change in the pattern of wetland habitat use for the brief periods of increased flow in the sprinkled areas. No change in the core area was detected at the end of the wet and dry season flow manipulations. The intermittent high flows still provide additional spray for the wetlands and as such is likely to be positive and increase the survival chances of the spray toad and its ecosystem. Whether flow manipulations, in a situation with a fully functioning sprinkler system, is cost-efficient conservation is another question that should be considered together with the essential continuous bypass flow of almost 2 m^3/s.

5.6 Alternative mitigation measures

Once the factors influencing the spray toad population sizes are better understood, it will be possible to plan mitigation measures to produce the desired toad population level. However, objectives in terms of the other unique species in the gorge may need to be considered before alternative mitigation measures are proposed.

5.7 Further studies

Although more is known about the ecology and populations of this toad than most other African amphibians, there is a lot of detail still to be discovered, which may be essential for saving the species from a global extinction.

5.8 Recommendations

The minimum bypass flow of about 2 m^3/s should under no circumstances be stopped. Since it is almost impossible to have a 100% fail proof means of artificial spray generation, it is considered that stopping the minimum bypass flow may lead to the global extinction of the Kihansi Spray Toad. The sprinkler systems (including intakes, sediment traps, filters, pipes, nozzles) need frequent monitoring and rapid actions if any failure or damage occurs. The minimum bypass flow and the sprinkler systems must act as mutual backups if the objective is to maintain a population of the Kihansi Spray Toad.

Monitoring of the biophysical conditions in the Kihansi Gorge should continue and provide documentation of the impacts of the Lower Kihansi Hydropower Project and efficiency of the mitigation measures. However, a balance between the ecological risks associated with this monitoring and the value of the information collected needs to be found. The Kihansi Spray Toad has not been found outside Kihansi Gorge, and it is considered unlikely to be found at a later stage either. We therefore need to act on basis of the precautionary principle and optimise the chances of its survival in the Kihansi Gorge Spray Wetlands.

On basis of the studies carried out so far the following recommendations are made:

1) The minimum bypass flow of about 2 m^3/s should be maintained at all times, and an adequate compliance monitoring system established and operated by an independent institution/organisation.
2) The sprinkler systems, or similar means of maintaining adequate humidity in the wetlands, should be well operated and maintained in the

long term by an institution with genuine interest in maintaining the Kihansi Gorge ecosystem.

3) Future monitoring should investigate the annual fluctuations in population size of the Kihansi Spray Toad in the Kihansi Gorge.

4) Studies of the Kihansi Gorge, its wetlands, and the unique spray toad, should be continued.

5) Experimental bypass flow manipulation should attempt to provide a flow equivalent to the mean pre-diversion dry-season flow of 7 m^3/s, over a longer period, in order to establish the difference between pre-diversion minimal flow and present-day flow.

6) The hypothesis that spray toads migrate along the river should be investigated.

7) Continued searching specifically for the Kihansi Spray Toad is not recommended. The chances of finding the species are considered extremely small.

8) The evaluation of translocation of the Kihansi Spray Toad is recommended to be continued with studies in the Upper and Lower Lufulutonya Spray Wetlands and the Udagaji Spray Wetland. Before a translocation is carried out additional and detailed studies need to be carried out.

9) It is recommended that the captive breeding efforts are continued, including studies of aspects of the ecology of the spray toad and close co-operation with studies in the field. The captive breeding institutions should receive financial support to carry out such work.

6 REFERENCES

Castanet, S., Loth M. and Lamotte, M. 2000. Âge individuel, longévité et dynamique de croissance osseuse chez un amphibien vivipare, *Nectophrynoides occidentalis* (Anoure, Bufonidé). *Ann. Sci. Nat.* 21: 11-17.

Channing, A., 2000. *Habitat loss and amphibian biodiversity: relict forests in Tanzania.* Report to the National Geographic Society, Washington D.C., U.S.A.

Channing, A., 2001. *Amphibians of Central and Southern Africa*. Cornell University Press, Ithaca.

Donnelly, M. A., and Crump, M.L., 1998. Potential effects of climate change on two Neotropical amphibian assemblages. *Climate Change* 39: 541-561.

Duellman, W. E. and Trueb, L., 1986. *Biology of Amphibians*. McGraw-Hill, New York. (xvii + 670 pp.)

Howell, K., Msya, C. and Kihaule, P., 1998. *Lower Kihansi Hydropower Project Environmental Monitoring Small Mammals, Amphibians and Reptiles*. A report of the Department of Zoology and Marine Biology. Report produced for NORPLAN / TANESCO. Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

IUCN, 2000. *IUCN Red List Categories*. Approved by the IUCN Council, Gland, Switzerland, February 2000.

Krebs, C. J. 1999. *Ecological Methodology.* Addison Wesley Longman, New York.

Kumbar, S. M., and Pancharatna, K., 2001. Occurrence of growth marks in the cross section of phalanges and long bones of limbs in tropical anurans. *Herp. Review* 32: 165-167.

Lee, S., 2000. Kihansi Spray Toad. Report No. 1. Wildlife Conservation Society, New York. U.S.A.

NORPLAN, 2002a. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Entomological Studies*. Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002b. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Vegetation Studies.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002c. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Micro-climatic Studies.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002d. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Artificial spray systems.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002e. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Searches/translocation.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002f. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Wet Season Flow Manipulations.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN, 2002g. *Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report: Dry Season Flow Manipulations.* Report prepared for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

Odland, A., 1990. *Endringer i flora og vegetasjon som følge av vannkraftutbyggingen i Aurlandsdalen*. NINA Forskningsrapport 15: 1-76.

Odland, A., Birks, H.H., Botnen, A., Tønsberg, T. and Vevle, O., 1991. Vegetation change in the spray zone of a waterfall following river regulation in Aurland, Western Norway. *Regulated Rivers: Research and Management* 6: 147-162.

Poynton J.C., Howell K.M., Clarke B.T. and Lovett J.C., 1998. A critically endangered new species of *Nectophrynoides* (Anura: Bufonidae) from the Kihansi Gorge, Udzungwa Mountains, Tanzania. *African Journal of Herpetology 47(2): 59 – 67.*

World Bank, 2000a. *Lower Kihansi Hydropower Project (LKHP) Environmental Review in Support of the National Environmental Management Council – Final Report*. World Bank, Washington D.C., U.S.A.

World Bank, 2000b. *Tanzania – Lower Kihansi Hydropower Project Follow-up of the Environmental Review and Identification of an Environmental Management and Capacity Building Project. Aide Memoire. October 16 – 26, 2000.* World Bank, Washington D.C., U.S.A.

Biodiversity and Conservation **14:** 297–308, 2005.

Effect of the Lower Kihansi Hydropower Project and post-project mitigation measures on wetland vegetation in Kihansi Gorge, Tanzania

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Abstract. Reduction in flow of the Lower Kihansi River, Tanzania, caused by implementation of a hydropower project in May 2000 has the potential to lead to changes in vegetation composition of spray maintained wetlands. These wetlands are the only known habitat for the Kihansi Spray Toad, *Nectophrynoides asperginis*. In this paper, change over time is assessed by comparing samples taken in 1998 before reduction in flow, with those taken in 2000 after reduction in flow, in 2001 following installation of a sprinkler system built to maintain the wetlands and in 2002 eighteen months after sprinkler installation. The vegetation was found to change markedly following initiation of the project, with marsh and stream side species dying back and weedy species entering the wetland. The wetland continued to change following installation of the sprinkler system and has not appeared to have reverted back towards the pre-project condition, although diversity and the proportion of marsh and stream side species are greater in 2002 than in 1998.

Introduction

Wetlands are considered important ecosystems but are under threat from human pressure, with riparian wetlands in particular affected by dam construction and river management (Mitsch and Gosselink 1993; Toner and Keddy 1997; Kingsford 2000). Riparian wetlands in Kihansi Gorge, part of the Tanzanian Eastern Arc range of mountains, are maintained by spray from large waterfalls rather than from ground water or flooding. For this reason they are a habitat type of very limited extent under remarkable ecological conditions (Zilihona and Nummelin 2001). There are few studies on wetlands of this type. Brassard et al. (1971) refer to similar habitats in Labrador, Canada, as meadows rather than wetlands and Odland et al. (1991) discuss vegetation changes in a western Norwegian spray zone following river regulation, although evaluation of mitigation measures did not form part of their study.

The importance of the Kihansi Gorge wetlands lies not just in the unusual nature of this ecosystem but because they provide the only known habitat for the Kihansi Spray Toad, *Nectophrynoides asperginis* (Poynton et al. 1998; Taplin et al. 1999). The Eastern Arc mountains, which are noted for their high number of endemic species (Frost 1985; Jenkins 1992) and are included in the top 25 biodiversity hotspots

(Myers et al. 2000), contain 30 endemic amphibian species with a further 40 near-endemic species (Burgess et al. 1998). The Kihansi Spray Toad was discovered in 1996 and has only recently been scientifically described (Poynton et al. 1998). It is believed to have one of the smallest ranges of any extant vertebrate (Klesius 2002).

Wetlands in Lower Kihansi Gorge, and hence the habitat of the Kihansi Spray Toad, are likely to change because of the development and operation of the Lower Kihansi Hydropower Project (LKHP) (Zilihona et al. 1998). The LKHP diverts water out of the gorge, causing loss of spray that maintains the wetland habitat of the Kihansi Spray Toad. The apparent conflict between development and conservation caused considerable debate, stimulated by the suggestion that electricity supply should be affected by conservation activities and needs (power cuts 'could be sparked' by battle to save toad; The East African (Nairobi), 19 October 2000). Since May 2000 the LKHP has been fully operational with a bypass flow of 1.5–1.9 $m^3 s^{-1}$, a marked reduction from an average natural flow of 16.3 $m^3 s^{-1}$ and dry season natural flow of 9.5 $m^3 s^{-1}$. This bypass flow is the highest possible without unacceptable (to the project owner and operator) levels of foregone electricity production (NORPLAN 2001a). Under this bypass flow, changes were observed in the wetlands. The soil became firm and distribution of the Kihansi Spray Toad across the wetlands has been reduced (personal observation). Since March 2001 a sprinkler system has been operating in the Upper Spray Wetland in an attempt to recreate the conditions required for the survival of the Kihansi Spray Toad. Under natural conditions spray onto the wetland varied between 75 and 1145 mm per day depending on proximity to the waterfall. The minimum output of the sprinkler system is 70 mm per day (NORPLAN 2001b).

The purpose of this study is to compare the vegetation in the Upper Spray Wetland between September 1998 (prior to the initiation of LKHP diversions), September 2000 (after 4 months with only by-flow water input but reduced flow since December 1999), September 2001 (6 months after sprinkler installation) and September 2002 (18 months after sprinkler installation) in order to assess the impact of the LKHP and the subsequent mitigation measures. The study was performed under the auspices of the LKHP Long-term Environmental Monitoring Programme (LEMP). LEMP was initiated in 1996, with the objective of identifying changes in the ecology of the Kihansi River Gorge caused by the construction and operation of the Lower Kihansi Hydropower Project. The LEMP activities include regular surveys of the project area biota to characterise the existing ecosystem and changes which are taking place.

Methods

Study area

Kihansi Gorge is in the southern part of the Udzungwa escarpment approximately 400 km from Dar es Salaam. The gorge runs north to south with Kihansi waterfall at its head and contains a strip of rainforest about 0.5 km wide and 2 km long. The

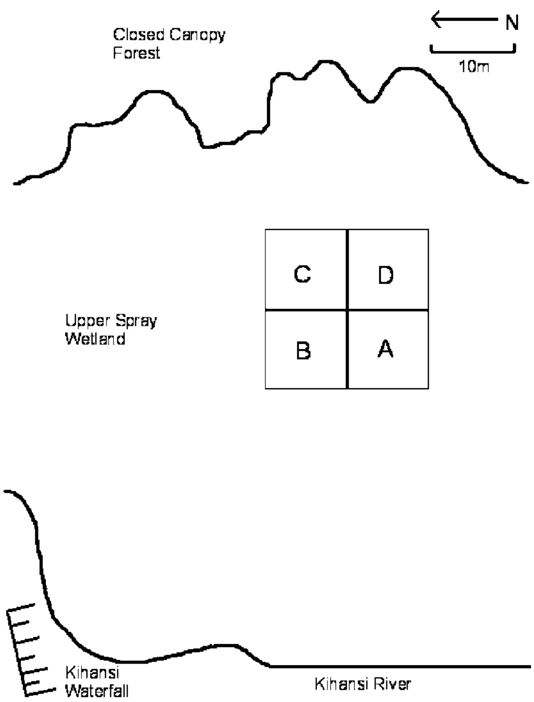

Figure 1. Diagram of the Upper Spray Wetland showing the location of the sample area.

forest contains tree species endemic to the Eastern Arc with some outside their usual altitudinal range (Lovett et al. 1997). This may be due to the unusual microclimatic conditions maintained in the gorge by the presence of the Kihansi River and waterfalls.

The Upper Wetland is the largest wetland in the Lower Kihansi Gorge at approximately 6090 m^2. In 1998 the main water input was spray from the largest waterfall in the gorge. In March 2001 a sprinkler system was installed in 2900 m^2 of the wetland in order to mimic the spray once produced by the waterfall.

Field methods

In 1998 most of the Upper Spray Wetland was inaccessible due to the large amounts of spray. A 20 m $\times$ 20 m area around a prominent rock in the centre of the wetland was chosen as the most feasible area for study using a random stratified sampling method. Sampling was repeated in September 2000–2002 to allow for comparison. In 2001 and 2002 the sampled area fell within the sprinkler mitigation area of the wetland. The 20 m $\times$ 20 m area was divided into four quarters, quarter B closest to the waterfall and quarter D furthest away (Figure 1). Random numbers were used to generate 10 sets of co-ordinates in each quarter and a wooden 1 m^2 quadrat was used to delimit the sampled area at each location. In each 1 m^2 quadrat all plant species were identified and their percentage cover recorded. The wetland vegetation was predominantly grass species, so counting individuals was not feasible and using biomass as an abundance measure would have meant unacceptable destruction of vegetation. Other measures such as Domin or Braun–Blanquet scales were not used as they are not linearly correlated with abundance and produce a biased result when used with diversity indices (Magurran 1988). Specimens of each species were collected and confirmation of their identification made at the Herbarium of the Department of Botany, University of Dar es Salaam, Tanzania and the Royal Botanic Gardens, Kew, England. Voucher specimens were also deposited at the Herbarium for future reference. The nomenclature used follows Hubbard et al. (1952) and Exell and Launert (1970). The guilds for each species were created from the habitat descriptions by Hubbard et al. (1952) and by reference to specimens at the Herbarium, University of Dar es Salaam.

Data analysis

For each species mean percentage cover for the whole of the sample area was calculated for each year. Shannon and Simpson indices were calculated for the whole 20 m × 20 m area as well as for each quarter in each year in order to investigate trends in diversity. Shannon's index is affected most by species richness, while Simpson's index is affected most by dominance and both are widely used (Magurran 1988). The Community Analysis Package (CAP) (Pisces Conservation Ltd 1999) was used to perform Detrended Correspondence Analysis (DCA) (Hill and Gauch 1980) to examine vegetation patterns in the 20 m × 20 m area for each of the 4 years. The axes produced by DCA provide a measure of the variation between each of the quadrats in the wetlands since each axis is calculated to capture the greatest variation between sample plots. Axis 1 captures the most variation, axis 2 the next, and so on. The closer the plots are in ordination space the more similar they are in species composition.

Results

Upper wetland changes 1998–2002

A total of 38 species in 18 families were identified in the 20 m × 20 m area of the Upper Wetland (Table 1). The highest number of species were found in 2002 with a total of 27 species in 14 families while the least number of species were found in 2000 (18 species in 12 families). Only 12 species were found to occur in all years. Four species were only found in 1998 and did not reappear in subsequent surveys, five species were first found in 2000 and went on to appear in one or both subsequent surveys, three species were only found in 2001 and 10 species appeared in the study area for the first time in 2002.

Table 1. Mean percentage cover for each species in the 20 m × 20 m area of the Upper Wetland 1998–2002 (arranged according to guilds as in Hubbard et al. 1952).

Guild	Species	1998 Pre-project	2000 By-flow	2001 6 months sprinklers	2002 18 months sprinklers
Marsh	*Cyperus exaltatus* Retz.	0.3			
	Impatiens nana Engl.	8.9	1.0	2.8	5.9
	Leersia hexandra Sw.	12.9	3.8	0.1	0.3
	Panicum parvifolium Lam.	4.5	5.4	1.3	0.4
	Polygonum nepalense Meisn.		0.03	1.8	5.5
	Hypericum scioanum Chiov.		0.6		6.9
	Polygonum salicifolium Brouss. ex Willd.		4.4		9.5
Stream side	*Begonia oxyloba* Welw. Ex Hook. f.	1.3			0.6
	Alchemilla kiwuensis Engl.	0.3	0.1	0.1	0.7
	Hypericum revolutum Vahl.	2.5	3.7	1.4	5.1
	Pilea rivularis Wedd.	12.4	1.0	0.7	7.9
	Streptocarpus buchananii C.B. Clarke	1.6	6.6	0.7	4.6
	Stephania abyssinica (Quart.-Dill & A. Rich) Walp.	0.9	1.7	0.8	3.0
	Coelachne africana Pilg.				0.6
	Elatostema monticola Hook. f.				0.4
Moist forest margin	*Costus afer* Ker Gawl.	1.4			
	Commelina benghalensis L.	0.2		0.4	
	Brillantaisia madagascariensis T. Anderson ex Lindau	5.4	4.4	16.1	21.9
	Drymaria cordata (L.) Willd. ex Schult.	2.9	0.03	8.2	6.6
	Selaginella kraussiana (Kunzel) A. Braun	22.1	24.0	2.9	7.1
	Aframomum mala (K. Schum. ex Engl.) K. Schum.				1.4
	Thunbergia alata Bojer. ex Sims				0.1
Forest margin	*Basananthe hanningtoniana* (Mast.) W.J. de Wilde	1.9			
	Rumex abyssinicus Jacq.	4.8		10.1	
	Rubia cordifolia L.			0.1	
	Vernonia auriculifera Hiern				0.2

Table 1. (continued).

Guild	Species	1998 Pre-project	2000 By-flow	2001 6 months sprinklers	2002 18 months sprinklers
Forest floor/shade	*Christella dentata* (Forssk.) Brownsy & Jermy	2.6			
	Tectaria gemmifera (Fée) Alston	0.1	0.3		
	Microstegium vagans (Nees ex Steud) A. Camus	13.5	41.1	42.9	7.2
	Thelypteris dentata (Forssk.) E.P. St. John		1.3		0.2
	Vernonia pteropoda Oliv. & Hiern			0.1	
	Microstegium nudum (Trin.) A. Camus				2.1
	Panicum trichocladum Hack ex K. Schum.				0.5
Disturbed weed	*Ageratum conyzoides* L.		0.2	0.1	
	Sonchus afromontanus R.E. Fr.			0.1	
	Cynodon dactylon (L.) Pers.				0.4
	Solanecio mannii (Hook. f.) C. Jeffrey				0.1
Unknown	*Panicum* sp.				1.1
Moss					0.1
Bare rock			0.6	9.5	

Table 2. Diversity indices for 1998–2002.

	Shannon diversity index				Simpson's diversity index			
	1998 Pre-project	2000 By-flow	2001 6 months sprinklers	2002 18 months sprinklers	1998 Pre-project	2000 By-flow	2001 6 months sprinklers	2002 18 months sprinklers
20 m × 20 m area	2.42	1.88	1.72	2.65	8.25	4.32	3.58	10.48
A	2.28	1.69	0.95	1.68	8.61	3.84	1.97	3.24
B	1.64	1.30	1.52	2.32	8.31	2.71	3.83	8.17
C	2.23	1.60	1.56	2.59	7.98	4.00	2.95	9.67
D	2.26	2.13	1.75	2.01	8.12	7.53	3.99	6.26

Average percentage cover for the 12 species that occurred in all years was not found to be significantly different between years ($\chi^2 = 4.1$, $\mathrm{df} = 3$, $p = 0.250$). However, some species increased in abundance while others decreased. Most species, while showing a fall in abundance in 2000 and 2001, had increased in abundance in 2002 with some species such as *Brillantaisia madagascariensis* and *Alchemilla kiwuensis* more abundant in 2002 than in 1998. In contrast, *Panicum parvifolium* consistently reduced in abundance throughout the sampling period.

The impact of changes in water input has varied according to species guild (Table 1). Marsh species present in 1998 declined or were lost from the wetland although the overall proportion of marsh species was greater in 2002 due to new species appearing. Stream side species faired better with increased abundance in 2002 after reduced abundance in 2000 and 2001. The proportion of stream side species was also greater in 2002 than in 1998. Moist forest margin species have shown the same pattern of decline in 2000 and 2001 followed by an increase in abundance in 2002, so that this guild too made up a larger proportion of species in the wetland in 2002 than it did in 1998. However, this increase was associated with a shift from *Selaginella kraussiana* as the dominant moist forest margin species to *B. madagascariensis*. The weed species first appeared in the wetland in 2000 but their proportion still remained low in 2002. The other guilds made up a smaller proportion of the wetland species in 2002 than in 1998.

Diversity indices

Shannon and Simpson diversity indices fell in the whole study area in 2000, after diversion of the Kihansi River, and in 2001, 6 months after installation of the sprinkler system (Table 2). However, both Shannon and Simpson diversity indices increased in 2002, 18 months after installation of the sprinkler system, to a level greater than that in 1998 before diversion of the river began. Each quarter has shown a similar pattern of change in diversity over the sampling period but diversity in 2002 is not higher than in 1998 in all quarters. Quarters B and C have a higher Shannon diversity index for 2002 than for 1998 while only quarter C has a higher Simpson diversity index for 2002 compared to 1998.

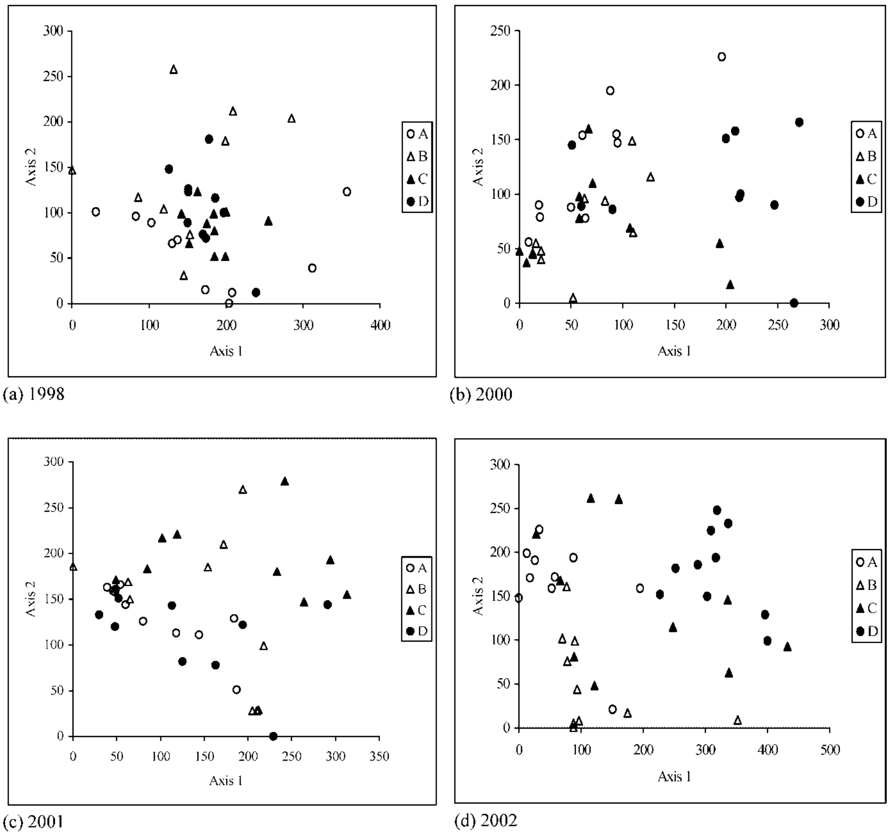

Figure 2. (a) DCA scores for all quadrats in 1998 indicating no major vegetation patterns (eigenvalues axis 1 = 0.45, axis 2 = 0.27). (b) DCA scores for all quadrats in 2000, with two distinct groups of quadrats visible along axis 1 (eigenvalues axis 1 = 0.53, axis 2 = 0.27). (c) DCA scores for all quadrats in 2001. Dominance by *Microstegium vagans* has created a cluster of quadrats (eigenvalues axis 1 = 0.62, axis 2 = 0.37). (d) DCA scores for all quadrats in 2002. Quadrats from quarters A, B and D have formed separate clusters while quadrats from quarter C are dispersed throughout (eigenvalues axis 1 = 0.73, axis 2 = 0.37).

Detrended correspondence analysis

Results from DCA of the 1998 data indicate no major patterns in the vegetation of the 20 m × 20 m area (Figure 2a). In 2000 two distinct groups of quadrats are visible along axis 1 (Figure 2b). The second group is predominantly comprised of quadrats from quarter D. This suggests a polarisation in vegetation composition across the wetland following reduction in river flow with quadrats further from the waterfall forming a separate group. Following establishment of the sprinkler system in 2001 this distinct grouping was no longer apparent in the data but instead a cluster of quadrats formed low down on axis 1 comprised of quadrats from all four quarters (Figure 2c). This group was defined by dominance by *Microstegium*

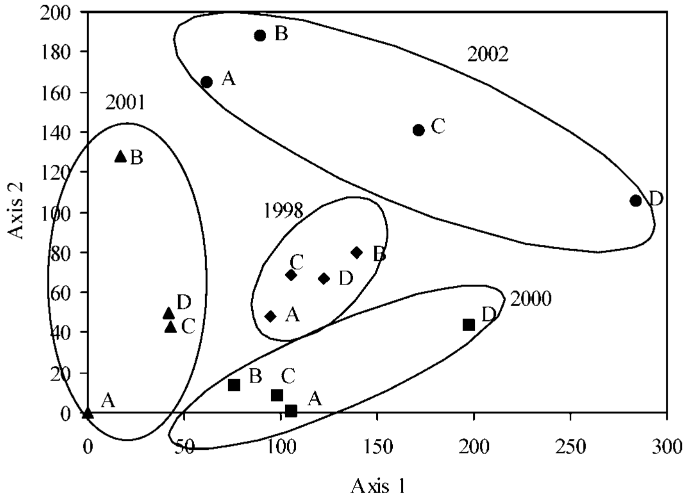

Figure 3. DCA scores for each quarter 1998–2002. The largest changes for each quarter were between 2001 and 2002 except for quarter B, where the most substantial change in composition occurred between 2000 and 2001 (eigenvalues axis 1 = 0.40, axis 2 = 0.26).

vagans with a percentage cover of 80–95% and did not appear to be related to distance from the waterfall. In 2002 the pattern of species composition changed again with the majority of quadrats from quarters A, B and D forming clusters while quadrats from quarter C were dispersed throughout (Figure 2d).

The results of the DCA of each quarter in each year showed a clustering of quarters from each year in the ordination space (Figure 3). The analysis indicates that the variation between the quarters was smallest in 1998 and species composition in the quarters changed the least between 1998 and 2000. The largest changes for each quarter were between 2001 and 2002 except for quarter B where the most substantial change in composition occurred between 2000 and 2001, possibly as a result of a time lag between the diversion of the Kihansi River and reaction to diversion by the plant community. None of the quarters has reverted towards the pre-project condition in 2002.

Discussion

The results clearly show there were significant and rapid changes in the Upper Spray Wetland vegetation following alteration of the Kihansi river flow and subsequent installation of a sprinkler system. When the river was diverted and prior to sprinkler initiation, a number of marsh and stream side species either disappeared from the area sampled, or substantially reduced in abundance. Weedy species appeared and the vegetation became polarised with respect to distance from the waterfall. Following installation of the sprinkler system polarisation of the vegetation was no longer apparent, but marsh species initially lost from the sampled area did not reappear as new marsh species took their place and *M. vagans* dominated in many areas. After 18 months of sprinkler mitigation the vegetation has not reverted back completely towards the pre-project condition although diversity has increased and the proportions of marsh and stream side species are greater than in 1998.

The 12 species present in the wetland throughout the sampling period have reacted differently to the changes in water input and associated microclimate change. This may be in direct response to the reduction in spray, as has been found to be the case for similar wetlands in Norway (Odland et al. 1991), or because of the associated changes in microclimate caused by water diversion. The spray conditions prior to diversion were responsible for maintaining stable low temperatures and high humidity in the wetland regardless of the macroclimate (NORPLAN 2002). Hence water diversion led not only to reduced water input but also lower humidity and larger temperature fluctuations. As a result many species reduced in abundance but other more resistant species were able to take competitive advantage. The engineering consultant for LKHP found that the sprinkler system adequately mimics pre-project conditions (NORPLAN 2002) and as a result many species have shown a recovery in abundance in 2002.

Studies suggest that temperature and humidity were generally consistent across the wetland regardless of distance from the waterfall prior to diversion (NORPLAN 2001b). This consistency in microclimate is reflected by the absence of any distinct patterns in the vegetation in 1998 with only small variation between the quarters. After river diversion and before sprinkler installation polarisation of the vegetation suggests that a vegetation gradient had begun to form with different plant communities close to the waterfall, where spray from the bypass flow was still entering the wetland, and further away. This may have been the result of changes in composition furthest from the waterfall as the wetland dried out. It has been suggested that vegetation furthest from the waterfall would by nature be more resilient and less likely to change following river regulation (Odland et al. 1991). Greater distance from the waterfall means that they will have experienced fluctuations in water input caused by seasonal changes in river flow and periods of drought in the past. Therefore, it is possible that the quadrats closer to the waterfall were more vulnerable to the reduction in water flow over the waterfall, creating the polarisation in vegetation cover. However, historical data suggests that even in the driest year (1956) average monthly river flow in the dry season did not fall below $6\,m^3\,s^{-1}$ (NORPLAN 1995), so bypass conditions were likely to have a major impact on the vegetation regardless of distance from the waterfall.

The impact of the mitigation measures has in general been positive. In 2000, 6 months after installation of the sprinkler system, some species were still declining in abundance and diversity losses had not been recovered. This may have been a result of a time lag in reaction to the changes. Quarter B had shown an increase in diversity while the other quarters were still declining, possibly as a result of the combined effect of the bypass flow and the sprinkler mitigation. Dominance by *M. vagans*, a species commonly found in forests (Hubbard et al. 1952), suggests that the diversion of water had given a competitive advantage to species that had wider habitat tolerances. After 18 months of mitigation, diversity overall has increased but as a result of new species entering the area rather than because of a complete recovery of all the pre-project species. However, mitigation has prevented wide scale colonisation by weedy species such as *Ageratum conyzoides*, a species known to colonise disturbed areas (Wild 1955; Ivens 1967). Although new weed species are still appearing their abundance has remained relatively low. Vegetation patterns are also now apparent in the wetland but their cause is not clear. Although the LKHP engineering consultant feels that the sprinkler system adequately mimics pre-project conditions (NORPLAN 2002) there are distinct differences in the species composition of quarters A, B and D. Since there are no other studies of sprinkler systems it is impossible to tell at present if this is a result of the mitigation or related to successional process in the wetland or species source-sink dynamics (N.J. Cordeiro, personal communication). It may be that the observed patterns are a positive step towards restoration to the pre-project condition but continued monitoring will be necessary to confirm if this is the case.

In terms of management recommendations arising from the results there are two key observations. Firstly, diversion of the Kihansi River caused rapid changes in vegetation of the Upper Spray Wetland. This is of importance because this area is an important habitat for the Kihansi Spray Toad. Secondly, installation and operation of a sprinkler system to mitigate loss of spray from the river has had some impact, but the vegetation did not return completely to its 1998 state within the sampling time period. Eighteen months after installation of the sprinklers diversity has increased and the proportion of marsh and stream side species has become greater than in 1998. Continued operation of the sprinkler system and monitoring of its effects is needed to evaluate its efficacy in the longer term.

At the time of writing, studies of long term irrigation system effectiveness and the possibility of varying LKHP bypass flows to preserve the Kihansi Gorge wetlands are continuing. The Government of Tanzania has made arrangements for captive breeding of the threatened Kihansi Spray Toad to ensure its survival in the short term.

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References

Brassard G.R., Frost S., Laird M., Olsen O.A. and Steele D.H. 1971. Studies of the spray zone of Churchill Falls, Labrador. Biological Conservation 4: 13–18.

Burgess N.D., Fjeldså J. and Botterweg R. 1998. Faunal importance of the Eastern Arc mountains of Kenya and Tanzania. Journal of East African Natural History 87: 37–58.

Exell A.W. and Launert E. 1970. Flora of Zambesiaca: Pteridophyta. Crown Agents for Overseas Governments and Administrations, London.

Frost D.R. 1985. Amphibian Species of the World: A Taxonomic and Geographical Reference. Allen Press Inc. & The Association of Systematics Collections, Lawrence, Kansas.

Hill M.O. and Gauch H.G. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42: 47–58.

Hubbard E.C., Milne-Redhead F. and Polhill R. 1952. Flora of Tropical East Africa. A.A. Balkema, Rotterdam, The Netherlands.

Ivens G.W. 1967. East African Weeds and Their Control. Oxford University Press, Nairobi, Kenya.

Jenkins M. 1992. Biological Diversity. In: Sayer J.A., Harcourt C.S. and Collins N.M. (eds) The Conservation Atlas of Tropical Forests, Africa. IUCN and Simon & Schuster, London, pp. 26–32.

Kingsford R.T. 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. Austral Ecology 25: 109–127.

Klesius M. 2002. The State of the Planet. National Geographic September 2002: 102–115.

Lovett J.C., Hatton J., Mwasumbi L.B. and Gerstle J.H. 1997. Assessment of the impact of the Lower Kihansi Hydropower Project on the forests of Kihansi Gorge, Tanzania. Biodiversity and Conservation 6: 915–933.

Magurran A.E. 1988. Ecological Diversity and its Measurement. Chapman & Hall, London.

Mitsch W.J. and Gosselink J.G. 1993. Wetlands. 2nd edn. Van Nostrand Reinhold, New York.

Myers N., Mittermeier R.A., Mittermeier C.G., da Fonseca G.A.B. and Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

NORPLAN 1995. Lower Kihansi Hydropower Project. Environmental Impact Assessment. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN 2001a. Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report – Economic analysis of bypass flow regimes. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN 2001b. Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report – Artificial spray systems. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

NORPLAN 2002. Lower Kihansi Hydropower Project. Immediate Rescue and Emergency Measures. Final Specialist Report – Micro-climatic studies. Report produced for Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

Odland A., Birks H.H., Botnen A., Tønsberg T. and Vevle O. 1991. Vegetation change in the spray zone of waterfall following river regulation in Aurland, western Norway. Regulated Rivers: Research and Management 6: 147–162.

Poynton J.C., Howell K.M., Clarke B.T. and Lovett J.C. 1998. A critically endangered new species of *Nectophrynoides* (Anura: Bufonidae) from Kihansi Gorge, Udzungwa Mountains Tanzania. African Journal of Herpetology 47: 59–67.

Taplin J., Lovett J.C. and McClean C. 1999. Conservation status and moisture requirements of the Kihansi Gorge vegetation. Report produced for NORPLAN A/S, Ski, Norway.

Toner M. and Keddy P. 1997. River hydrology and riparian wetlands: a predictive model for ecological assembly. Ecological Applications 7: 236–246.

Wild H. 1955. Common Rhodesian Weeds. Government Printers, Salisbury, UK.

Zilihona I. and Nummelin M. 2001. Coleopteran diversity and abundance in different habitats near Kihansi waterfall, in the Udzungwa Mountains, Tanzania. Biodiversity and Conservation 10: 769–777.

Zilihona I., Heinonen J. and Nummelin M. 1998. Arthropod diversity and abundance along the Kihansi Gorge (Kihansi River) in the Southern Udzungwa Mountains, Tanzania. Journal of East African Natural History 87: 233–240.

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Section 4:
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THE BIOLOGY AND RECENT HISTORY OF THE CRITICALLY ENDANGERED KIHANSI SPRAY TOAD *NECTOPHRYNOIDES ASPERGINIS* IN TANZANIA

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ABSTRACT

The ovoviviparous Kihansi spray toad *Nectophrynoides asperginis* is known from only one locality in the Udzungwa Mountains, Tanzania. At the time of discovery in 1996 the species occurred in a spray wetland habitat of about 4 ha maintained by spray from falls on the Kihansi River. River flow was diverted for hydropower production in late 1999, causing the habitat to desiccate, threatening the toad population and other plants and animals dependent on the spray wetland habitat.

We conducted field studies from January 2001 to November 2002 in 12 visits, with additional counts through to June 2003. Here we report on the changes in population numbers in the light of the mitigation measures introduced from 2001 in an attempt to maintain a habitat suitable for the Kihansi spray toad. Some data on life history are presented. This small toad is now restricted to an area of less than 2 ha. Due to a reported population crash in late 2003, variously attributed to pesticide use upstream, chytrid fungus, or safari ants (*Dorylus* sp.), the Kihansi spray toad may be effectively extinct in the wild. The actual cause of the population crash is not known.
Key words: Tanzania, Kihansi spray toad, Hydropower, Threatened, *Nectophrynoides*, Mitigation.

INTRODUCTION

The chain of mountains running along the eastern side of Tanzania, known as the Eastern Arc, represents areas with some of the highest biodiversity in Africa (Myers *et al*., 2000; Newmark, 2002; Burgess *et al*., 2003). The Eastern Arc is a global biodiversity hotspot defined partly on the high numbers of endemic amphibians, both caecilians and frogs (Brooks *et al.*, 2001, 2002), which represent the dominant endemic vertebrate group (Burgess *et al.*, 1998). Toads in the family Bufonidae are remarkably diverse, with a number of African genera present such as *Churamiti* Channing & Stanley, 2002, and *Nectophrynoides* Nobel, 1926. Both of these are endemic to the Eastern Arc Mountains, and many species of the latter genus are reported to be ovoviviparous (Menegon *et al.*, 2004). All 12 species described and assigned to this genus are restricted to montane environments in Tanzania. These are the Kihansi spray toad *Nectophrynoides asperginis* Poynton *et al.* 1999 (Udzungwas), the Uluguru forest toad *N. cryptus* Perret, 1971 (Ulugurus), the Frontier forest toad *N. frontieri* Menegon *et al.* 2004 (East Usambaras), the smooth forest toad *N. laevis* Menegon *et al.* 2004 (Uluguru South), the Ukaguru forest toad *N. laticeps* Channing *et al.* 2005 (Ukagurus), the dwarf forest toad *N. minutus* Perret, 1972 (Ulugurus), Poynton's forest toad *N. poyntoni* Menegon *et al.* 2004 (Udzungwas), the pseudo forest toad *N. pseudotornieri* Menegon *et al.* 2004 (Uluguru North), Tornier's forest toad *N. tornieri* (Roux 1906) (Usambaras, Ulugurus, Udzungwas), Vestergaard's forest toad *N. vestergaardi* Menegon *et al.* 2004 (West Usambaras), the robust forest toad *N. viviparus* Tornier, 1905 (Ulugurus, Udzungwas, Porotos, Mt Rungwe), and Wendy's forest toad *N. wendyae* Clarke, 1989 (Udzungwas) (Menegon *et al.*, 2004; Channing *et al.*, 2005). At least one further species from the Ukaguru Mountains awaits description.

Three species of *Nectophrynoides* have been accorded the highest level of conservation concern, as Critically Endangered, by IUCN - the World Conservation Union (IUCN, 2005): *N. poyntoni, N. asperginis* and *N. wendyae*. The genus is listed by CITES in Appendix I (as *Nectophrynoides* sp., listed 1 July 1975). The genus is also controlled through the USA Endangered Species Act.

The eastern slopes of the Udzungwa Mountains are abrupt, with fast-flowing rivers. One of these, the Kihansi River, drains a highland area through the Kihansi Gorge in the southern Udzungwa Mountains. The Kihansi Gorge is steep sided and relatively narrow. The stable flow and large height variation of the gorge made it an attractive site for hydropower generation. With an average flow of 16.3 $m^3.s^{-1}$ and a gross head of almost 853 m the project has the potential to provide a significant proportion of Tanzania's power supply. Construction of the USD 275 million Lower Kihansi Hydropower Project (LKHP) started in July 1994 with funding from a group of bilateral and multilateral donors.

The Kihansi spray toad, *Nectophrynoides asperginis,* (figure 1) was first discovered in December 1996, in areas of spray wetland associated with the Kihansi Falls (Poynton *et al.*, 1999). This was after construction of the LKHP had started. Since late 1999 up to 24 $m^3.s^{-1}$ of the flow in the Kihansi River has been diverted, resulting in a major reduction, or even removal, of the spray created by the Kihansi Falls. Under natural conditions the large quantities of spray from the waterfall have an effect throughout large areas of the gorge, and in particular in the spray wetlands, of maintaining higher and more stable relative humidity and lower and more stable temperatures. The mean spray precipitation under average flow conditions of 16.3 $m^3.s^{-1}$ is 300 $mm.day^{-1}$. This extremely high moisture regime and strong winds created a unique habitat and prevented forest trees from growing near the falls, resulting in wetlands where grass and moss-like vegetation was dominant.

The desiccation of the wetland during 2000 resulted in the initiation of an emergency project to protect the Kihansi spray toad and its wetland habitat, which was funded by the Norwegian Agency for Development Cooperation (Norad) and the Swedish International Development Agency (Sida). Some of the results from the emergency project studies are presented below.

Figure 1. An adult Kihansi spray toad Nectophrynoides asperginis.

DESCRIPTION OF STUDY SITE

Spray wetlands

The spray wetlands that provide the habitat for the toad are restricted to the Kihansi Gorge on the edge of the Udzungwa Escarpment at 8°35′ S; 35°51′ E (figure 2). The Kihansi Gorge is approximately 4 km long, steep sided, narrow, with a north-south orientation. The Kihansi River drops about 853 m over a series of waterfalls, to the bottom of the gorge. The largest of the falls, with a drop of approximately 100 m, is located at the head of the gorge. The relatively large size (*ca*. 685 km^2) of the Kihansi catchment means that the Kihansi River has a higher and more reliable flow than other rivers draining the escarpment. The original spray wetland habitat extended in small patches along about 2 km of the river, with a total area of about 4 ha.

There are five discrete areas of spray wetland habitat in the Kihansi Gorge between 650 and 1050 m. These are the Main Falls Spray Wetland (MFSW), the Upper Spray Wetland (USW), the Lower Spray Wetland (LSW), the Mid Gorge Spray Wetland (MGSW), and the Mhalala Spray Wetland (MSW). A small area of spray wetland at the entrance to the gorge was found to have a few toads, but this is not considered further. The Upper Spray Wetland had 89% of the gorge population of spray toads in October 2000 (Newmark, 2002), and will be the primary focus here. Many results are similar for all wetlands. A brief description of each wetland is presented in Appendix 1.

The Mhalala Spray Wetland is small, situated on the western side of the Kihansi River, and fed by a small river that is not affected by the diversion of the main river. This wetland may also have received some spray from the falls of the Kihansi River before diversion. As the Mhalala River seemed independent of the main river after diversion, and the habitat was fragile, we decided not to undertake routine surveys there in order to minimise disturbance.

The spray wetlands prior to river diversion were characterised by low, dense, grassland vegetation, including such species as *Panicum* grasses and the spike-moss *Selaginella kraussiana* (Kunze) A.Braun. The lowest vegetation was found towards the falls where the wind and spray generated by the falls were strongest. Towards the edges of the spray wetlands larger plants, such as *Aframomum mala* K.Schum. and *Costus afer* Ker Gawl., were found. The spray wetlands are surrounded by tropical humid forest.

Under natural conditions the spray wetlands experienced almost constant 100% relative humidity and lower and more stable temperatures compared to other areas of the gorge that were outside the spray wetlands.

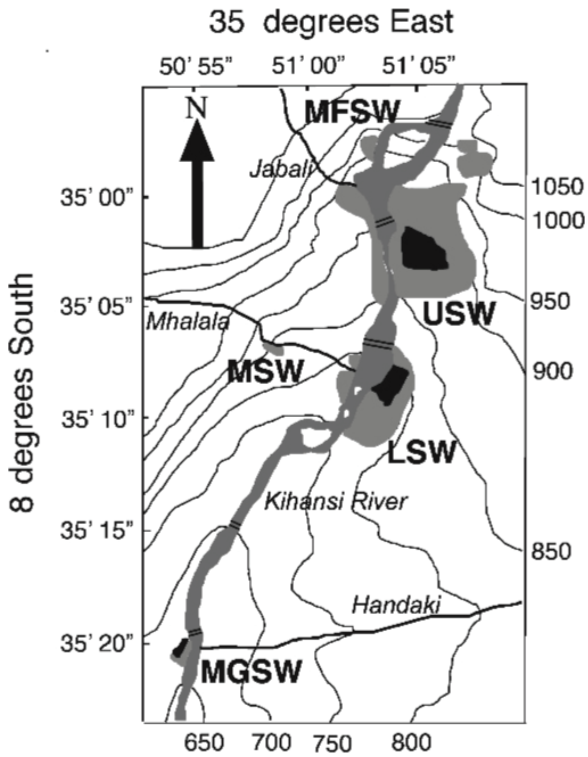

Figure 2. Map of the Kihansi Gorge. Sprinkler areas are indicated in black. Spray wetlands are shown in grey, indicating their extent before diversion. Waterfalls are indicated by two parallel bars across the river. Scale: The arrow indicating north represents 200 m.

Mitigation measures

During the first year following commissioning of the hydropower project in 2000 several of the spray wetlands in the Kihansi Gorge suffered severe desiccation. On the basis of field observations made in October 2000 (Newmark, 2002) it was estimated that the area of wetland that was receiving spray was reduced by about 92% in the USW and 100% in the LSW. This meant a major reduction in the area of habitat available for use by the spray toad, with some minor variation in the reduction depending on the river flow and time of day.

Besides maintaining a small minimum bypass flow released from the dam, other mitigation measures included a captive breeding programme for the spray toad established by several zoos in the USA (Lee, 2000). Ecological studies were carried out on the spray toad and the spray wetlands. These included determining the amount of spray generated by different bypass flow rates, the effect of intermittent high bypass flows from the dam, and the spray generated by a jet fountain. Searches were made for other potential spray wetland habitats along the Udzungwa Escarpment and the option of translocation was investigated. Only some of the results are reported here.

A system of sprinklers consisting of nozzles mounted 1–2 m above the ground to obtain a minimum input of 70 $mm.day^{-1}$ was installed. This was the precipitation input estimated in the centre of the USW under a natural river flow of approximately 20 $m^3.s^{-1}$.

The USW sprinkler system was constructed in March 2001. The system covers an area of approximately 2900 m^2, and uses approximately 6.5 $l.s^{-1}$ of water obtained from the Jabali intake (a small stream located on the west bank of the Kihansi River) and a portion of the minimum bypass flow from the dam.

Temperatures and relative humidity (RH) are relatively constant in the spray wetlands, under the artificial sprinklers, examples being 20° C, 95% RH (April 2001), 16° C, 90% RH (June 2001) and 15° C, 80% RH (August 2001).

One of the biggest concerns with activities in the spray wetlands, in terms of both construction and carrying out studies and monitoring, was the damage caused by human presence. Moving around in the wetland caused great damage to the vegetation and the soil structure especially when the soil was receiving water input. In addition, there was a risk of trampling on spray toads.

This was partly mitigated by constructing stepping stone walkways in the USW in July 2001. In total just over 170 m of walkways were installed in the Upper Spray Wetland.

MATERIALS AND METHODS

Core area

During counts of spray toads in vegetation plots carried out in 2001 it was noted that the toads occupied only part of the area within the USW. This area changed in size and position through the year, and was termed the core area. The core area concept was used as the basis for the analysis of data. All gorge spray wetlands have shown this spatial and temporal variation in habitat use and the core area concept was applied throughout.

Population estimates

The Kihansi spray toad uses both vegetation and rock habitat in the spray wetlands. The populations were estimated separately in these two habitats, and combined to find the total. Once the counts in the vegetation were completed for a sampling session the core area was defined by marking the plots counted on a sketch map, and joining the outermost plots where spray toads were found, in the form of a polygon. This core area was then used to determine the average density of spray toads and a population estimate.

Vegetation population estimates were obtained using stratified sampling. Transects were usually run west-east or north-south with approximately 5 m between each transect line.

Quadrats of 0.5 m x 0.5 m were placed at roughly 2 m intervals along the transects. The quadrats were marked in each corner with a rod, and then systematically searched. The vegetation was moved aside until the whole quadrat had been checked. Occasional pauses in searches allowed for observation of toad movement. Any amphibians that were found were removed from the quadrat. All species were recorded.

A mean of about 186 quadrat counts was carried out in spray wetland vegetation during each of 6 sampling sessions in the USW from February to October 2001. Of these 874 were undertaken inside the sprinkler system, and 240 outside of the sprinkled area. During this time the 13 permanent rock plots in the USW were each counted 164 times, a mean of 16 in ten visits.

Although randomly located plots would improve the statistical power of the counts it was decided that plots located along transects would be more appropriate as trampling damage to the habitat of the critically endangered spray toad would be minimised.

The majority of the plots were inside the sprinkled area as this was the area with most spray toads. Some plots were located outside the sprinkled area for comparison.

On the basis of the quadrat counts, a density of spray toads was calculated. Population estimates within 95% confidence intervals were determined for the vegetation of the USW. As the transects extended across the whole spray wetland, it was possible to make comparisons with counts taken by other workers before 2001.

Altogether 13 permanent sampling plots, each approximately 1 x 1 m, were established on rocks distributed over the USW, permanently marked with metal tags attached by expansion bolts. All rock plots are within the wet area covered by the sprinkler system and most are on vertical or near-vertical rock faces. The number of spray toads in each sample plot was counted and the mean density value was multiplied by an estimate of the size of wet rock habitat to obtain a population estimate. This method provided a quick means of monitoring the spray toad population and a method for following patterns of movement throughout the day. In addition, total counts of all spray toads observed on bare rocks in the spray wetlands were carried out at least once during each sampling session.

The total USW population estimate was obtained by combining the rock and vegetation estimates.

Confidence intervals were calculated using the BCa bootstrap (Efron & Tibishirani, 1994). Not all the spray wetlands were sampled each session. When calculating the total toad population estimates in the gorge, these gaps were dealt with by accumulating the data in the following order: USW, MGSW, MFSW, LSW and MSW. The accumulation stopped as soon as a region with missing data was encountered.

Reproduction and growth

During each survey attempts were made to identify toads found as juveniles, subadults, adult males and adult females. Females that were clearly gravid and pairs in amplexus were noted. In order to monitor toad growth, a random sample of 26 males and 35 females was taken in April 2001, measured, weighed, and returned where they were found. Snout-urostyle length (SUL) was measured using a vernier caliper, and approximate weights were determined for small groups of similar-sized toads, using an electronic top-loading balance (Ohaus CS-200). The weights were allocated in proportion to the length of the animal. It was not possible to weigh each animal separately as the field balance was only accurate to 0.1 g.

After observing that there was movement of toads on to rock faces at night, we tested if the rock habitat was used by smaller younger toads, or older, larger animals. Students t-test (2-tailed) showed that the lengths of toads collected from rock or vegetation were not significantly different ($p>0.10$, $t=2.1098$). Subsequent growth measurements were therefore made on animals collected from rock faces as these could be quickly collected, measured, and returned. A comparative sample was taken in August 2001, consisting of 18 males and 8 females. Developing tadpoles were staged according to Gosner (1960).

Behaviour and habitat use

General information on behaviour, vocalisation, and activity levels was collected. Counts of the spray toad were made for 24 hours on rock plot 4 in March 2001. Other counts were made at dusk and dawn at various later dates, but are similar to the March 2001 count, and are not discussed further.

Diet

Gut contents were analysed from specimens accidentally collected when they jumped into insect traps. These comprised 19 specimens from October 1997; 12 specimens from October 1998 and 17 specimens from October 1999 (all from before diversion of river flow). Additional specimens (26 from the USW, October 2000; 3 from the MSW, October 2000; and 25 from rock faces in the LSW, October 2000) from after diversion of the river were included for comparative purposes and to increase sample size.

Predation and disease

We observed predation events on the toad, and recorded the presence of potential predators in the spray wetlands. All animals obtained were checked for gross abnormalities, and any dead animals found were collected for later inspection. Toe tips were removed from animals accidentally collected in insect traps, in order to check for the presence of chytrid fungus.

Aerial surveys

With the apparent demise of the Kihansi Gorge spray wetland habitats, the possibility was examined of translocating the toads to other suitable habitats. Aerial surveys were carried out in the dry season in order to identify other large waterfalls along the Udzungwa Escarpment that had the potential for creating spray zones and thus spray wetland habitat. There are many rivers that have a high flow during the wet season, but in order to have any chance of supporting populations of spray toads, a river will need to have adequate dry season flow as well. A survey was carried out in late August 2001 that covered 180 km along the length of the Udzungwa Escarpment. On the basis of the aerial surveys a number of potential sites were identified and visited on foot in order to carry out searches for the spray toad and obtain preliminary measurements of spray generation, temperature and relative humidity. Wherever possible searches were carried out at night, the time at which the spray toad is most active and easily observed.

RESULTS

Population estimates

Table 1 shows core area sizes estimated for the USW. The core areas were found to always include the base of the falls.

The earliest USW population estimate showed a density of 4.7 toads per m^2 in the vegetation (Poynton *et al.*, 1999). The toads were distributed across the entire spray wetland,

Table 1. Population estimates for the Upper Spray Wetland. Rock population estimates marked with an asterisk are based on toad density on the 13 permanent rock plots. TC=total count.

Survey date	Vegetation			Rock			Total population estimate
	Core area (m^2)	Population estimate	95% CI	Core area (m^2)	Population estimate	95% C	
October 1998 (based on Poynton *et al*., 1999)	4290						20163
October 2000 (Newmark, 2002)	578	2310	952–3668	284	8540	3989–13091	10850
January 2001	1330	6087		125	211		6299
February 2001	1900	4180	2277–6080	470	610	119–1101	4790
March/April 2001	1330	1729	998–2594	125	23*	13–33	1752
April/May 2001	900	1232	568–2084	125	26*	16–37	1258
June 2001	2654	5073	4132–6114	389	168*	136–201	5241
August 2001	962	2058	1432–2774	389	282*	168–397	2340
October 2001	2593	7097	5277–9371		521	TC	7618
December 2001	2593	7667	5388–10361		572	TC	8239
March 2002	2900	7602	5643–9979		60	TC	7602
September 2002	2593	12067	8776–16256		496	TC	12067
June 2003	2900	17745	14673–21279		233	TC	17745

which we conservatively estimate covered 66 x 65 m, or 4290 m^2. The population estimation of 20163 before diversion in Table 1 is based on this calculation.

The first population estimate carried out in the USW after diversion in October 2000 gave a mean estimate of 10850 (Newmark, 2002). The population continued to decline to a lowest mean estimate of around 1250 in April/May 2001, immediately after the installation of the wetland sprinkler system. Subsequently the population of the spray toad in the USW increased steadily over the following 2 years to a maximum of 17745 in June 2003. Table 2 shows the Kihansi gorge population estimates between October 2000 and June 2003.

Table 2. Total gorge population estimates for the Kihansi spray toad, 2000–2003.

Spray wetland	USW	LSW	MSW	MFSW	MGSW	Gorge total
October 2000	10850	763	96	470	14	11385
June 2001	5241	296	500	5812	1140	13000
October 2001	7618	323	746	763	1703	11200
December 2001	8239	381	500	524	1415	11059
March 2002	7602			1196	2461	11320
September 2002	12067			1238	1052	14358
June 2003	17745			707	2536	20989

Reproduction

Two common call types are heard in the spray wetlands; the advertisement call and the male aggression call. Each advertisement call consists of one to four pulses per note. The emphasised frequency is 4.2 to 4.4 kHz, and the pulses are produced at a mean rate of 167 per second. Calls are heard throughout the year, with a peak in the rainy season of January-February. The aggression call consists of a long sequence of notes, effectively a series of advertisement calls strung together.

Males usually congregate and form choruses while concealed in vegetation. Calling has been heard mostly during the day and at a lower intensity after dark. Males produce the aggression call when another male approaches within about 200 mm directly in front of a calling male.

Amplexus is most often seen on wet rock surfaces, and is common during the day. The female presses her abdomen close to the substrate, and the male cloaca is closely adpressed to the female. Amplexus is prolonged, but no details of the duration have been recorded in the field. Amplexus is axillary, with the male forearms clasped under the arms of the female. The sex ratio was nearly 1:1 in the USW vegetation and rock habitats (47 males: 40 females).

The Kihansi spray toad is ovoviviparous: fertilisation is internal, and the tadpoles are retained within the oviducts where they develop into small frogs before they are born. Clutch size varied from 5–13. Juveniles are purple with lime green markings in the form of irregular longitudinal stripes. The adults are bright yellow with dark brown lateral stripes and a dark sacral blotch. Subadults are intermediate in colour pattern, with traces of purple background changing to bright yellow.

The timing of reproductive activity as measured by proportions of pairs in amplexus, gravid females, juveniles, and subadults, was similar in all wetlands examined, both those with and without sprinklers.

During the August/September 2001 dry season many adult individuals showed slight enlargement of the abdomen, and it was difficult to decide in the field if these were gravid females. The examination of a sample of these putative gravid females using transmitted light and a dissecting microscope permitted the contents of the abdomen to be seen through the thin belly-skin of live animals. Only two of ten females examined were gravid, one with two well-developed juveniles, and the other with early stage 30 tadpoles. The abdomens of all females and one male examined were filled with fluid, suggesting that the bladder is serving as a water-storage organ at this time of the year. Most adult individuals observed in August showed this enlarged abdomen. In some it was more obvious than in others.

In addition, many of the adult spray toads observed in August 2001 did not show the bright yellow background with strongly contrasting brown markings that are thought to be typical for the species. Most were a dull, nearly uniform brown. The brown colour extends along the upper side of the limbs and covers the top of the two outer toes and fingers. Associated with this colour change is a roughening of the skin with the accentuation of black-tipped spines along the limbs of some animals examined.

Growth

The two sexes were significantly different in length in April 2001 (t-test, $p<0.003$, $t=3.824$) and also in August 2001 (t-test, $p<0.00001$, $t=-8.188$).

The growth of males was determined by comparing the lengths of samples measured in April and August. The samples were significantly different (t-test, $p<0.05$, $t=-2.1249$). The mean length of the males in April was 16.7 mm, compared to 17.6 mm in August.

The females were also significantly different in length between April (mean 18.4 mm) and August (mean 21.8 mm). The t-test was highly significant ($p<0.000001$, $t=-6.9443$). The largest female measured 28 mm SUL.

In order to determine the growth trends for the whole USW population, the lengths of both sexes were pooled, so that a comparison could be made between the April and August samples. The difference was significant (t-test $p<0.008$, two-tailed). The mean April length was 17.7 mm compared to the mean in August of 19.1 mm.

Recruitment of subadults into the population by October 2001 leads to a smaller mean size. The mean length in August 2001 of 19.1 mm decreased to 15.6 mm in October 2001. This is significant (two-tailed t-test, $p<0.00001$).

Behaviour and habitat use

Changes in river flow result in dramatic changes in water level, spray quantity and wind strength in the spray wetlands. The toads on the rocks at the river edge move quickly to stay above water level, while remaining in areas receiving spray, when river flow fluctuates. They avoid areas of very strong wind where the spray is blowing horizontally. These very strong winds from the base of the falls have been seen to blow adults off rock faces. Toads close to the river easily escaped an increase in river flow of more than 400% in less than an hour during flow manipulation tests.

Juveniles were always found at ground level, while subadults were plentiful within the vegetation, especially in the mat of roots and stems found along the ground, and never seen on the upper surface of the vegetation. Adults were present from ground level, to the upper surfaces of the highest plants. Juveniles were never found on the vertical rock faces and very few subadults were observed on rock faces. The adults were common on wet rocks, including vertical and even overhanging faces.

Toads are more visible in the vegetation at night, when they sit on high leaves, presumably foraging. There is a movement of toads on to rock faces after dark, most of these vertical or near vertical, with a return of most toads to the vegetation after daybreak. This is illustrated by the following counts, which show the 24 hr activity cycle for toads on permanent rock plot 4 in March 2001. The data are presented as time and count of toads on the rock face: 00h00-40; 03h00-35; 06h00-24; 09h00-4; 12h00-2; 15h00-4; 18h00-20; 21h00-35; 24h00-40.

Most toads on vertical rock faces were not disturbed by people passing nearby. Those that were, would either climb upwards and shelter under overhanging vegetation, or drop off the rock to disappear in the vegetation below.

During the dry season large numbers of spray toads were found aggregating under wet rock overhangs and on vertical rock faces near the base of the falls, with the highest numbers on the west side facing the base of the falls from where the natural blown spray originates. This is illustrated by sample counts from New Frog Rock, a large slab of rock near the base of the falls, where a daytime mean of 29.1 toads in the wet season (June 2001), increased to 137.0 in the dry season (August 2001). This extreme aggregating behaviour was not seen in the wet season.

During the rainy season toads are bright yellow, with smooth skin, and the population was distributed throughout the part of the wetland that received spray. Vocalizations were heard day and night, and many gravid females were present. A large increase in juveniles towards the end of the season was recorded.

Diet

Adults feed on the top leaves of broad-leafed plants such as *Brillantaisia* P.Beauv. (Acanthaceae), within the vegetation in grass or mosses, or on wet rock faces. Feeding appears to occur both during day and night.

The spray toad adopts three main methods of foraging. The first is to sit and wait, becoming active only after a flying insect lands nearby. The second strategy is to actively patrol on broad-leafed vegetation or wet rock surfaces, where they may lunge at adult insects or larvae wriggling in the water film. The third strategy is to stalk larger insects such as flies. There was continuous foraging by small numbers of frogs on spray-blown rocks, both during cool overcast times, and when the sun was out and the rocks were beginning to warm up.

Only a brief summary of the results of the gut content study is given here; a full analysis based on both numerical proportions and volumetric estimates will be presented in a separate paper.

A total of 1692 food items were identified in the gut content analyses, of which about half originated from pre-diversion samples. A wide variety of arthropods was found, including representatives of 18 orders, but insects formed the majority (88.5%) of the diet. The major insect groups identified were Diptera (60.4%), Homoptera (9.7%) and Hymenoptera (7.6%), with Acarina (mites) (11.4%) being the only non-insect group forming a significant portion of the diet. Together these four groups constituted 89.1% of all items identified and with the addition of the Collembola, Coleoptera and Trichoptera, formed 96.3% of the diet, the remaining 11 orders making up only 3.7%.

The above analysis is based on numerical proportions; a more accurate indication of relative importance of prey items could be obtained by calculating relative food values by using the measurements taken to estimate the volume of each item, but this was beyond the scope of the initial study.

The majority (54.1%) of the Diptera eaten were larvae of the eucephalic type, with 5.0% being other types of dipteran larvae and 40.9% adult Diptera. The eucephalic larvae were most likely those of the numerous species of midge-like flies abundant in the spray wetlands and were observed both on wet rock faces and on the wetland vegetation. The high proportion (36.1%) in the diet is probably only a result of the abundance of these larvae that resulted from the continuous spray producing a large area of habitat suitable for these aquatic larvae on the rocks as well as on the vegetation. The mean number of identifiable prey items per toad was 18.8.

Predation and disease

The only recorded predators are the commonly seen freshwater crab *Potamonautes* sp. and safari ants *Dorylus* sp., which were seen to invade the wetland in December 2001. Snakes *Philothamnus* sp. were sometimes found sleeping in the drier vegetation at the edge of the wetland and there was one observation of an unidentified snake in the heavy spray zone at night on top of one of the rocks which had many toads on its vertical faces. No animals with obvious symptoms of disease were found. The results of the chytrid fungus investigation will be reported on elsewhere.

Aerial surveys

Following the aerial surveys a number of waterfalls with potential spray wetland habitat were identified. However, none of these waterfalls were of a comparable size to the Lower Kihansi Falls and spray generation was much more limited. The spray toad was not found in any of the sites searched (table 3) along eight river systems in the Udzungwa Mountains. The Kihansi spray toad is still only known from a single locality, the Kihansi Gorge.

Table 3. Sites examined for possible translocation.

Waterfalls visited	Co-ordinates	
Igolimbogo, November 2001	08º14’51” S	36º03’31” E
Izanga, November 2001	08º13’18” S	36º03’30” E
Kifufu, November 2001	08º14’48” S	36º03’49” E
Kiselesi, November 2001	08º14’16” S	36º02’14” E
Masisiwe Gorge (Lovett *et al*., 1998), May 2001; August 2001 (Upper gorge not visited)	08º25’13” S	35º58’24” E
Msingusi, November 2001	08º16’12” S	36º03’42” E
Sanje Falls (Lovett et al., 1998), October 2001	07º46’54” S	36º53’59” E
Udagaji Gorge (Howell, 1999), June 2000, June 2001; August 2001	08º36’57” S	35º52’20” E
Ungwilo, November 2001	08º19’23” S	36º03’31” E
Upper Lufulutonya Spray Wetland (Howell, 1999), June 2000, May 2001	08º33’13” S	35º51’20” E

Other Amphibians

All amphibians recorded in or near the Kihansi gorge spray wetlands are listed below. The taxonomy follows Frost *et al*. (2006).

Arthroleptidae

Common squeaker *Arthroleptis stenodactylus* Pfeffer, 1893
This species is widespread, present on the edge of the spray wetlands.

Eastern squeaker *Arthroleptis xenodactyla* Boulenger, 1909
This small frog is present in the spray wetlands, with a density of 12 in 22.5 m^2 in the USW in March 2001. At this density the population estimate was 1325, 95% CI 549-2102, which

is 75% of the estimated size of the spray toad population at that time. However, in none of the 90 quadrats counted, did both species occur together. At other times of the year the density of these leaf litter frogs was much lower.

Uluguru tree frog *Leptopelis uluguruensis* Barbour & Loveridge, 1928
This tree frog was found at the edge of the LSW. Specimens were reported throughout the study.

Bufonidae
Kihansi spray toad *Nectophrynoides asperginis* Poynton *et al.*, 1999
Present in all the spray wetlands.

Tornier's forest toad. *Nectophrynoides tornieri* (Roux, 1906)
This species is present around all the spray wetlands, also in areas receiving some spray.

Hyperoliidae
Fornasini's spiny reed frog *Afrixalus fornasini* (Bianconi, 1849)
Only one specimen was found.

Spotted reed frog *Hyperolius puncticulatus* (Pfeffer, 1893)
Only one specimen was found.

Petropedetidae
Southern torrent frog *Arthroleptides yakusini* Channing *et al.*, 2002
This frog is common in all the spray wetlands.

Rhacophorida*e*
Southern foam-nest frog *Chiromantis xerampelina* Peters, 1854
Only one specimen was found.

DISCUSSION

Spray toad biology

The Kihansi spray toad is one of the smaller members of the family Bufonidae. Average body lengths are around 20 mm with weights of 0.3 g. The largest adult females reach nearly 30 mm and weigh 0.8 to 0.9 g. Adult spray toads are usually 10 to 20 mm in size with yellow colouring and variable dark brown dorsal markings. Colouration varies between the wet and dry season. They have extensive webbing with rounded but not expanded toe tips. The spray toads are able to climb vertical wet rock surfaces. The feet are paddle-like with thick webbing between the toes that extends into a friction pad under the foot with only a trace of subarticular tubercles. There is a loose-skin friction pad on the palm without clear palmar or subarticular tubercles. The other species in this genus that climb vegetation have enlarged digital tips.

Population estimates

The following factors are likely to introduce variation and uncertainty to the determination of the spray toad population sizes: decreased detectability of the very small juveniles compared to the larger subadults and adults, possibly resulting in underestimation of the juvenile proportion; and the use of transects which can be prone to systematic error since they are inherently non-random.

Biological censuses are usually subject to some element of observer bias. In order to reduce this source of error a small group of observers was used wherever possible.

Other commonly used methods of monitoring populations, such as mark-recapture techniques, were discussed initially but not used. The small size of the animals, and a severely reduced population of the critically endangered spray toad meant that handling of the toads was kept to a minimum to reduce stress levels and reduce the potential risks of disease spreading. There was concern that capturing, marking and handling could affect survival rates of the spray toad. It also appears that many individuals have a very limited range over the period of a single sampling session and apparently little movement and mixing of individuals occurs. This would violate an important assumption of this method, indicating that mark-recapture is not a suitable means of monitoring the population.

The highest density of spray toads in the vegetation was recorded in the Main Falls Spray Wetland in June 2001, when it reached 20 frogs.m^{-2}. This wetland did not have a sprinkler and was entirely dependent on spray generated from the minimum bypass flow.

The fact that there was an apparently stable overall population in the gorge despite relatively large fluctuations in individual wetlands (table 2) can be explained by the implementation of mitigation measures. The MGSW and LSW, which both had sprinklers installed throughout this project showed relatively little variation. The USW, following installation of the sprinkler, showed an overall increase in the population. Much of the variation in the overall gorge population is attributed to the change in the population in the MFSW. This population declined dramatically during the dry season of 2001, from 5812 in June 2001, to 524 in December 2001, as the habitat dried out during the dry season once spilling over the dam stopped and the bypass flow was reduced to 1.5 – 1.9 $m^3.s^{-1}$.

The factors that might have caused the initial observed decline in 2000 and early 2001 in the spray toad population include reduced river flow due to diversion resulting in a dramatic reduction in natural spray generation, natural die-off of older individuals and human disturbance from sprinkler construction activities and ecological sampling.

The factors that might have caused the toad population to increase after April 2001 include increased natural spray from increased river flow during the period of spilling from the dam (April–May 2001), spray from artificial sprinklers installed in mid-March 2001, combined with natural recruitment of juveniles into the population.

In order to maintain a permanent population under natural conditions, the habitat must provide abundant food in the form of small insects for the adult frogs, very small insects for the juveniles, shelter and high humidity. The structure of the habitat should include wet and low growing vegetation (e.g. grasses, small herbs and the spike-moss *Selaginella kraussiana*) and wet rock faces. It does not appear that the spray toad has specific requirements in terms of insect food species or plant species in its habitat.

Reproduction

The captive breeding programme has shown that the spray toads can live for more than three years, and that they can breed at around nine months old (Lee, 2003).

In the field, breeding is strongly seasonal, with peaks in amplexus from December to February. During January and February there is a peak in gravid females, followed by a high percentage of juveniles in March through to May. Sub-adults reached a peak in May, June and July. During August there is a large proportion of small adults and large subadults, suggesting that the new generation made up a substantial fraction of the population. The presence of juveniles through the wet season (March to June) was also observed in the MFSW. This supports the suggestion (Poynton *et al.*, 1999) that the breeding season is extended. The population appears to consist solely of adults in December, January and February.

The synchronous breeding activity in wetlands with and without sprinklers indicates that the artificial sprinklers are not a stimulus for breeding. In other amphibians rainfall, temperature, and daylength have been shown to be involved with seasonality of breeding (Duellman & Trueb, 1986).

The slightly expanded abdomens of many toads in the spray wetland during the dry season, both males and females, appears to be due entirely to water, stored in the bladder. Even a few females with embryos had nothing but fluid in the posterior abdomen. This kind of "pseudo-gravid" state was not recorded earlier in the year.

Growth

The analyses of male and female growth indicate that, on average, all the individuals in the population were growing. This could suggest that the bulk of the population represented essentially a single cohort, probably originating after the introduction of sprinklers. Alternatively, this is a boom-and-bust species, with rapid population growth followed by a population crash, followed by another growth phase. Very dense populations such as these of the spray toad could be expected to show this pattern. A related West African species, *Nimbaphrynoides occidentalis*, reaches 5 years in females and at least 2 years in males, based on bone growth rings (Castanet *et al.*, 2000).

Behaviour and habitat use

Seasonal variation in moisture and wind in the spray wetlands determines where the toads are present. The core area as used by the spray toads is dynamic, even within the sprinkler area. Toads appear to select wet areas without excessive wind energy. It is remarkable that they are able to respond rapidly to changes in spray patterns caused by differences in river flow rate, and suggests that this may be one of the reasons for their success in this naturally variable habitat. During experimental releases of water from the reservoir, the wind and spray on the rocks at the base of the falls increased dramatically over a period of 10–30 minutes. During the wet season (June 2001) toads on New Frog Rock decreased from 29.1 before the increased flow (1.8–2.4 $m^3.s^{-1}$), to 13.5 during the increased flow (2.9–4.0 $m^3.s^{-1}$). During brief flow manipulations in the dry season (August 2001), toad numbers decreased from 137.0 before the flow (2.0 $m^3.s^{-1}$), to 90.3 during the flow (4.0 $m^3.s^{-1}$ for 2 hrs). This behaviour was seen in all spray wetlands.

The Kihansi spray toad is an example of an extreme specialist. Humidity seems to be the single most important factor for habitat selection. The thin skin restricts the toad to cool, humid areas, while the small size and climbing ability allow it to live on the vertical rock faces within the direct spray zone of the various falls. Food is mostly small insects that themselves feed on the vegetation in the spray wetlands. It appears that much of the reproductive behaviour takes place within the vegetation and on wet rock faces.

The use of the habitat appears to be determined by toad age, amount of spray and wind, and time of day. Juveniles are found only at ground level on the soil or at the base of vegetation where there are plenty of small food items. Sub-adults were usually found in the wetland vegetation but on occasion were seen on rocks. Adults forage on vertical wet rock faces, on top of the vegetation, or in the three-dimensional habitat within the vegetation.

Toads are found where the habitat is wet from spray and never in the dry areas. In periods of very high river flow, when the spray is driven by strong winds from the base of the falls, the toads avoid the areas of strong wind and move into areas with spray that are not used in the dry season. There is also a strong diurnal movement of adults from inside the vegetation on to rock surfaces and vegetation tops during the night. After installation of the sprinklers adults would often be seen sitting out on the plastic pipelines and metal support posts in large numbers at night. When the weather is hot or dry the toads are often concealed in the vegetation or in the shade on wet rock faces.

The observations over the year indicate that many toads have home ranges, as particular individuals can be seen feeding in exactly the same place over a number of days. On the other hand, the toads are able to move rapidly when conditions are cool and wet, and there are no permanent barriers to migration throughout the gorge. The Kihansi River itself can be crossed. The fact that there are spray toad populations at various locations along both sides of the river indicates that migration occurred historically and that there must have been exchange of individuals between the sub-populations. This is less likely after diversion as there are large dry areas between remaining spray wetlands.

The toad appears to be associated with wetland plants, rather than with particular plant species. Common plants that are used by the toads in the spray wetlands include *Selaginella kraussiana, Leersia hexandra* Sw.*, Pilea rivularis* Wedd.*, Impatiens digitata* Warb. and *Brillantaisia madagascariensis* T.Anderson ex Lindau. The spray toad prefers wet vegetation, although they have been seen foraging for insects on high dry leaves when they can retreat into humid vegetation below.

They are found on vertical or near-vertical rock faces where the water from the spray drains. The pad-like structure of the webbing of the foot and the palm of the hand enables the toads to move over vertical wet surfaces and easily climb wet rock overhangs.

Most of the adults observed in August 2001 showed a darkening and roughening of the skin and the development of small dark-tipped spines, visible with a lens. The roughening of the skin approaches the condition of the integument in terrestrial bufonids, such as *Nectophrynoides tornieri* from the adjoining forest. In these and similar species the thicker glandular skin probably serves as a water-conservation mechanism. The associated increase in body fluid in the abdomen suggests that this species has developed a water conservation strategy for the dry season. This strategy is known from other amphibians; the Texas toad *Bufo cognatus* Say 1823 can retain nearly one third of its body weight as water in the bladder (Ruibal, 1962), and some tree frogs adopt the same strategy (Main & Bentley, 1964).

The distinct seasonality in the biology of the spray toad suggests that it is a dry-season *versus* wet-season response, but when more data are available it might prove to be more complex. The observations were made while the sprinkler system was maintaining a very wet, insect-rich vegetation throughout the USW.

Diet

It has been reported that food items pass through the digestive system of small frogs in approximately 8 hours (Johnson & Christiansen, 1976). If the spray toads feed continuously this would imply a maximum estimate of 56 prey items eaten per day (average number of items found was 18.8 per toad), with a minimum of about 19 items in the unlikely event that all toads were collected shortly after completing a once-daily feeding session. Only about 45% of the gut contents was estimated to be identifiable, so these estimates could be too low by as much as a factor of two. The actual number of items eaten per day thus probably falls between 20 and 100.

The diet of the adult and juvenile toads was very similar, with the only apparent difference being that juveniles ate more Collembola and Acarina, which are both groups of extremely small species and therefore probably of little food value to adults. However, these differences were not statistically significant.

The leafhopper *Afrosteles distans* Linnavuori, 1959 and an undescribed species of ensign scale, *Ortheziola* sp., were the commonest identifiable species in the gut contents both of adult and juvenile control groups. However, as the spray toads are generalist feeders, with a total of 18 arthropod orders and probably hundreds of species represented in their diet, these two species together constituted only 9.2% of the diet in numerical terms. Both were extremely abundant in the vegetated areas adjacent to the rocks on which the toads were collected and were the visually dominant insect species in the pre-diversion wetlands.

The taxonomic level to which prey items can be identified varies for different taxa, as well as for different stages in the life cycle. This is due in part to differences in their resistance to the digestive process, in part to varying levels of familiarity of the researcher with different arthropod groups and in part to differences in how readily apparent the identifying characteristics within groups are. Thus softer-bodied prey species and stages (for example many Collembola and Diplura, the softer-bodied spiders which may have only their fangs strongly sclerotised, and many larvae) may be rapidly broken down to an unrecognisable state, while others may pass through the entire digestive process in a readily identifiable form and may even be identified in faecal samples. In addition, larger prey items are often broken down into many small fragments while smaller species may pass through the digestive system with their exoskeletons virtually intact. As a result, a few items could be identified to species and some to family level, while most were identifiable only to order.

The spray toad is a generalist predator, feeding on a wide variety of arthropod species. The relatively high proportions of *Afrosteles distans* (2.6%) and *Ortheziola* sp. (6.6%) in the diet of pre-commissioning specimens is almost certainly a reflection of the high abundance of these species rather than any preferential feeding by the toads. Similarly, the high proportion of Diptera (60.4%), in particular Dipteran larvae (36.1%), in the diet is also probably due to the abundance of this group, although only subjective impressions of abundance are available to support this view. However, the significantly higher relative diversity of Diptera in the USW observed during long-term monitoring studies from 1997–2001, in conjunction with the slightly higher numbers of dipteran specimens collected by Malaise trapping prior to commissioning, add further support.

Although there are some groups, such as the Isopoda (woodlice) and Araneae (spiders), which the toads appear to avoid, they probably do not have any specific food requirements other than that there should be an adequate supply of prey items within a suitable size range (approximately 0.3 mm–10.0 mm).

Predation and disease

Very few events of predation on the Kihansi spray toad have been recorded. The only predators observed were crabs *Potomonautes* sp. that were commonly seen in the spray wetlands and safari ants *Dorylus* sp. that were rarely seen in the spray wetlands. Given its relatively large size it is considered likely that the commonly seen torrent frog *Arthroleptides yakusini* represents a predator. Snakes *Philothamnus* sp. have been observed in the spray wetlands and are also considered to be likely predators of the Kihansi spray toad. The adult toads' extensive use of vertical rock faces may be an anti-predator strategy.

Observations of safari ants entering the spray wetland and capturing Kihansi spray toads in early December 2001 show that predation by this species is indeed a risk for the toad, but if the safari ants were able to enter the wetland under artificial spray, it is likely that they were able to do so under natural spray as well. In the latter case occasional predation by safari ants would have been a natural occurrence which sufficient numbers of toads were able to avoid in order for the population to survive.

Evidence of disease in the Kihansi spray wetlands was not observed during field visits. The 499 adult toads transported to the USA in 2000 for captive breeding were initially infected by lungworm (Lee, 2001) suggesting that this is present in the spray wetlands. However, none of the small number of specimens from the wild dissected here showed any evidence of disease or high lung parasite load. Chytrid fungus *Batrachocytrium dendrobatidis* was detected in some dead frogs collected late in 2003 (Weldon & Du Preez, 2004). Chytrid is endemic in Africa (Weldon *et al.* 2004), and follow-up studies are in progress to survey other amphibian populations in the area. Chytrid has been found in other amphibians in the gorge area such as *Arthroleptides yakusini* and *Ptychadena* sp. (Weldon & Du Preez, 2004).

The influence of possible disease or predation on the toad population has not been determined, however.

Mitigation measures

During the year following diversion of river flow and before emergency mitigation measures were put in place the available habitat of the spray toad was dramatically reduced. The newly discovered species and probably other unique plants and animals in the Kihansi Gorge were at great risk of extinction. After the implementation of the various mitigation measures the situation for the spray toad improved somewhat with a reduced, artificially maintained, habitat. Although the Kihansi spray toad population increased following the installation of the artificial sprinklers and an immediate extinction was avoided this species remained probably the most endangered amphibian in Africa.

The minimum bypass flow (1.5–1.8 $m^3.s^{-1}$) available since the start of diversion has been important in terms of maintaining a small area of natural spray. However, the bypass flow has an alternative value in terms of the potential for producing electricity. In a developing country with limited electricity generation capacity the minimum bypass flow is seen as carrying an extremely high cost and many townspeople consider the spray toad to be the cause of power shortages, judging from letters to the newspapers.

Although an initial disaster was avoided by the implementation of mitigation measures at Kihansi these measures are difficult to maintain in the long term. The artificial sprinkler systems, which are at risk from damage by falling trees and rocks, fire, and general wear and tear, will require continual monitoring and maintenance, and that will depend upon a long-term commitment. Thus far the mitigation and monitoring measures have been funded by external donors.

The Kihansi spray toad has only been found in wetlands along the rivers in the Kihansi Gorge. The toad is absent from the nearby Udagaji and other gorges, despite day and night time searches by different groups from 1997–2002 (Howell *et al.*, 1997, 1998; Lovett *et al.*, 1998; Howell, 1999).

Planning and environmental impact assessments

The late discovery of the Kihansi spray toad during the process of implementing the Lower Kihansi Hydropower Project has had far-reaching effects. The species was only discovered after construction of the project had started, thus limiting the potential for modifying construction plans. This situation highlights the vital importance of timely and adequate environmental baseline studies and impact assessment (EIA) for avoiding ecological disasters as well as maintaining economic viability of large infrastructure projects. The original EIA did not include field work at the base of the Kihansi Falls, the area most severely affected by the proposed hydropower project, although it is known that such areas often contain unique or rare plants and animals (Brassard *et al.*, 1971; Odland *et al.*, 1991).

The desiccation of the Kihansi Gorge affects more than just the spray toad, including, for example, arthropods (Zilihona *et al.*, 1998), although the area is too small to affect endemic bird species (Dinesen, 1998).

IS THE KIHANSI SPRAY TOAD NOW EXTINCT?

In late June 2003, some days after tests had been made allowing high flows from the dam to determine the amount of spray created, large numbers of dead butterflies, millipedes, and toads were reportedly found in the Upper Spray Wetland. Subsequent searches into early 2004 have produced very few or no toads (Lee, 2003; Weldon & Du Preez, 2004). This toad is Africa's most endangered amphibian. Ironically, it is now also the most field-studied amphibian in Africa.

At the height of the success of the mitigation measures in late 2002 when the USW population had climbed from a low of 1250 in March 2001, to a high of over 17 000 in September 2002, a small number of dead toads was seen in the wetland. Previous to this event, the occasional dead toad was found, possibly the result of predation or trampling.

Sometime after that reports began to surface that the population had crashed dramatically. It appears that high levels of pesticide had been used upstream, and this was suggested as a reason for the population decline (Newmark, pers comm), but we are unaware of the results of any detailed investigation of pesticide runoff or residual concentrations. Chytrid fungus was found on some of the dead toads collected in September 2003 (Lee, 2003; Weldon & Du Preez, 2004). Our study showed that safari ants were able to enter the spray wetland. These super-predators would be able to make short work of small toads that have nowhere to escape to, and no coping mechanism. All this is, however, speculative.

No other habitats with populations of the spray toad were found during searches along the Udzungwa Escarpment. At this stage it must be assumed that the spray toad only exists in the Kihansi Gorge. Extinction of the Kihansi spray toad from the Kihansi Gorge would mean global extinction of the species in the wild.

The age at which breeding takes place, and the age structure of the population, has implications for the time taken for population numbers to recover after a severe reduction, such as happened in the Kihansi Gorge after diversion. Short-lived species will be better able to recover numbers in a short time, although longer-lived species may be able to better cope with prolonged adverse conditions. The strategy used by any species is selected for over long periods. The ability of the population of spray toads to recover, will depend on the number of animals remaining. The toad may not be able to survive if changes continue to happen in the gorge.

The original shipment of 499 animals to captive breeding facilities in North America has been maintained in various institutes; by April 2005 the captive population was 142 (Lee, *in lit*). The gorge habitat is being maintained (Weldon & Du Preez, 2004), and if small numbers of toads have survived, they should be able to rebuild the population over the next few years.

The stark reality, however, may be that this small toad, first discovered in 1996, is already extinct.

The conservation problem in the Kihansi Gorge could have been avoided if an initial comprehensive EIA had been carried out in time. The lines of control and oversight of environmental surveys in many third-world countries require support, and this needs to be considered by first-world donors of large infrastructure projects.

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REFERENCES

Brassard, G.R., S. Frost, L. Marshall, O.A. Olsen & D. H. Steele (1971). Studies of the spray zone of Churchill Falls, Labrador. *Biological Conservation* **4**: 13–18.

Brooks, T.M., A. Balmford, N.D. Burgess, J. Fjeldså, L.A. Hansen, J. Moore, C. Rahbek, and P. Williams (2001). Towards a blueprint for conservation in Africa. *Bioscience* **51**: 613–624.

Brooks, T.M., C.G. Mittermeier, G.A.B. Da Fonesca, A.B. Rylands, W.R. Konstant, P. Flick, J. Pilgrim, S. Oldfield, G. Magin & C. Hilton-Taylor (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* **16**: 909–923.

Burgess, N., J. Fjeldså & R. Botterweg (1998). Faunal importance of the Eastern Arc Mountains of Kenya and Tanzania. *Journal of East African Natural History* **87**: 37–58.

Burgess, N., T. Butynski, I. Gordon, Q. Luke, P. Sumbi & J. Watkin (2003). *Ecosystem profile—Eastern Arc Mountains and coastal forests of Tanzania and Kenya biodiversity hotspot*. Conservation International and International Centre of Insect Physiology and Ecology.

Castanet, J., S. Pinto, M.M. Loth & M. Lamotte (2000). Âge individuel, longévité et dynamique de croissance osseuse chez un amphibien vivipare, *Nectophrynoides occidentalis* (Anoure, Bufonidé). *Annales des Sciences Naturelles-Zoologie et Biologie Animale* **21**: 11–17.

Channing, A. & W.T. Stanley (2002). A new tree toad from the Ukaguru Mountains, Tanzania. *African Journal of Herpetology* **51**: 121–127.

Channing, A., M. Menegon, S. Salvideo & S. Akker (2005). A new forest toad from the Ukaguru Mountains, Tanzania (Bufonidae: *Nectophrynoides*). *African Journal of Herpetology* **54**: 149–157.

Dinesen, L. (1998). Priorities for biodiversity conservation in the Udzungwa Mountains, Tanzania—based on bird data. *Journal of East African Natural History* **87**: 195–204.

Duellman, W.E. & L. Trueb (1986). *Biology of Amphibians*. McGraw-Hill, New York.

Efron, B. & R.J. Tibishirani (1994). *An Introduction to the Bootstrap*. Monographs on Statistics and Applied Probability 57,. CRC Press. Boca Raton.

Frost, D.R., T. Grant, J. Faivovich, R.H. Bain, A. Haas, C.F.B. Haddad, R.O. DE SA, A. Channing, M. Wilkinson, S.O. Donnellan, C.J. Raxworthy, J.A. Campbell, B.L. Blotto, P. Moler, R.C. Drewes, R.A. Nussbaum, J.D. Lynch, D.M. Green & W.C. Wheeler. 2006. The amphibian tree of life. *Bulletin of the American Museum of Natural History*. **297**: 1–370.

Gosner, K.L. (1960). A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* **16**: 183–190.

Howell, K.M. (1999). Continued Search for the Kihansi Spray Toad. Report on Fieldwork Carried out in March 1999 by Howell, K. and Kihaule P.M. Long Term Environmental Monitoring project. Report produced for NORPLAN A.S. and the Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

Howell, K.M., C.A. Msuya & P. M. Kihaule (1997). Kihansi Fieldwork Report: 21 Oct.–10 Nov. 1997. Small Mammals, Amphibians and Reptiles. Report prepared for NORPLAN/TANESCO, Dar es Salaam, Tanzania.

Howell, K.M., C.A. Msuya & P. M. Kihaule (1998). LKHP Environmental Monitoring—Small Mammals, Amphibians and Reptiles, October 1998. Report prepared for NORPLAN/TANESCO, Dar es Salaam, Tanzania.

IUCN (2005). 2005 IUCN Red List of Threatened Species. www.redlist.org. [Accessed 6 August 2005].

Johnson, B.K. & J.L. Christiansen (1976). The food and food habits of Blanchard's cricket frog, *Acris crepitans blanchardi* (Amphibia, Anura, Hylidae) in Iowa. *Journal of Herpetology* **19**: 63–64.

Lee, S. (2000). Kihansi Spray Toad. Report No. 1. Wildlife Conservation Society, New York.

Lee, S. (2001). Kihansi Spray Toad. Report No. 2. Wildlife Conservation Society, New York.

Lee, S. (2003). Kihansi Spray Toad. Report No. 8. Wildlife Conservation Society, New York.

Lovett, J.C., L.A. Hansen & E. Mulungu (1998). Preliminary Report of Environmental Studies carried out for the Lower Kihansi Hydropower Project, July 1997. Report produced for NORPLAN A.S. and the Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

Main, A.R. & P.J. Bentley (1964). Water relations of Australian burrowing frogs and tree frogs. *Ecology* **45**: 379–382.

Menegon, M., S. Salvidio & S.P. Loader (2004). Five new species of *Nectophrynoides* Noble 1926 (Amphibia Anura Bufonidae) from the Eastern Arc Mountains, Tanzania. *Tropical Zoology* **17**: 97–121.

Myers, N., R.A. Mittermeier, C.G. Mittermmeier, G.A.B. Da Fonesca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 852–858.

Newmark, W.D. (2002). *Conserving Biodiversity in East African Forests. A study of the Eastern Arc Mountains*. Ecological Studies Vol. 55. Springer-Verlag, Berlin.

Odland, A., H.H. Birks, A. Botnen, T.Tønsberg & O. Vevle (1991). Vegetation change in the spray zone of a waterfall following river regulation in Aurland, Western Norway. *Regulated Rivers: Research and Management* **6**: 147–162.

Poynton, J.C., K.M. Howell, B.T. Clarke & J.C. Lovett (1999). A critically endangered new species of *Nectophrynoides* (Anura: Bufonidae) from the Kihansi Gorge, Udzungwa Mountains, Tanzania. *African Journal of Herpetology* **47**: 59–67.

Ruibal, R. (1962). The adaptive value of bladder water in the toad, *Bufo cognatus*. *Physiological Zoology* **35**: 218–223.

Weldon, C. & L.H. du Preez (2004). Decline of the Kihansi Spray Toad, *Nectophrynoides asperginis*, from the Udzungwa Mountains, Tanzania. *Froglog* **62**: 2–3.

Weldon, C., L.H. du Preez, A.D. Hyatt, R. Muller, & R. Speare. 2004. Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* **10**: 2100–2105.

Zilihona, I., J. Heinonen & M. Nummelin (1998). Arthropod diversity and abundance along the Kihansi Gorge (Kihansi River), Tanzania. *Journal of East African Natural History* **87**: 233–240.

Appendix 1. A brief description of the five discrete areas of spray wetland habitat in the Kihansi Gorge

Upper Spray Wetland
This lies on the east bank of the Kihansi River at an altitude of 850-950 m . Before diversion this wetland covered an area of 70 x 90 m. The northern part consists of rock faces. The accessible section is covered by low vegetation near the falls, such as the moss Selaginella kraussiana and Panicum grasses, and higher vegetation such as Costus afer further from the falls. A large rock on the eastern slope is termed Old Frog Rock, as spray toads were clustered there before diversion.

Lower Spray Wetland
This is located below the USW, on the east side of the river, between 750 and 800 m. Before diversion it covered an area of 100 x 70 m. It is a steep area with less uniform vegetation than the USW. A small section of the wetland is found on the west side of the river, where the Mhalala River joins the Kihansi River.

Mid-gorge Spray Wetland
This lies on the west bank of the river at 650 m. It is small (24 x 10 m), and covered by a dense mat of tangled vegetation. The wetland is surrounded by tall forest.

Mhalala Spray Wetland
This is the only spray wetland not along the Kihansi River. It is situated about 100 m west of the Kihansi River, at 850 m, and receives spray from the small Mhalala River. The wetland is small, 24 x 10 m, and steep. The Mhalala River has a catchment of only 16.6 km^2, but under natural flow conditions the spray is augmented by spray from the Kihansi falls, particularly in the wet season.

Main Falls Spray Wetland
This small wetland is situated at the base of the main falls, at 1000 m. It is mostly boulders and rock slopes, with some low vegetation. This wetland was only easily accessible after ladders and a bridge were constructed.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 5:
Chytrid Fungus

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Amphibian Chytridiomycosis
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Chytridiomycosis is an important emerging disease of amphibians caused by the chytrid fungus *Batrachochytrium dendrobatidis* (Bd). Although previously classified within the Kingdom Protista, organisms in the Phylum Chytridiomycota ("chytrids") are now known to be true fungi that produce characteristic motile posteriorly uniflagellate zoospores within discrete fungal bodies termed thalli. Chytrids are ubiquitous in aquatic environments and while several species are known pathogens of plants, fungi, or invertebrates, none were reported to infect vertebrates until the description of Bd in amphibians (Berger 1998; Longcore 1999). To date, only Bd has been associated with amphibian disease and Koch's postulates have been fulfilled (Nichols 2001).

Preliminary reports of chytridiomycosis in the late 1990s described Bd as either an aquatic fungal-like protist or a *Perkinsus*-like protozoan. In addition, some reports of infection with *Basidiobolus ranarum* in toads were instead subsequently determined to have been due to infection with Bd (Pessier 2002; Muths 2003). Infection has now been recognized in a wide range of both anuran (frogs and toads) and urodele (salamanders and newts) amphibians. A report of infection in the order Gymniophona (caecilians) is anecdotal and needs to be confirmed (Mylniczenko 2003). Although a significant disease problem in both captive and free-ranging animals, chytridiomycosis is most important because of an association with mass mortality events and population declines in the United States, Europe, Latin America, and Australia (Berger 1998; Green 2002; Muths 2003; Bosch 2001; Bradley 2002). Concerns about the effects of chytridiomycosis on free-ranging populations, including the possibility of disease-associated extinctions, have resulted in calls for ex-situ species salvage and breeding programs that may significantly impact zoological collections.

Chytridiomycosis and Amphibian Population Declines

Amphibian population declines have been increasingly recognized since the late 1980s and have generated much public and scientific interest. A recent survey suggests that 32.5% of known amphibian species are globally threatened and 43.2% are experiencing a population decrease (Stuart 2004). Although in some declines a clear anthropogenic cause such as habitat loss or species exploitation can be implicated, in many others the cause is not obvious ("enigmatic decline"). Of the enigmatic-type population declines, chytridiomycosis and climate change are most frequently cited as potential causes.

Population declines attributed to chytridiomycosis are best documented in stream dwelling species at high elevations in the rainforests of Central America and eastern Australia (Lips 2003; Woodhams 2005). In both locations there has been suggestion of temporal and geographic progression of declines (Daszak 1999). The apparent southward progression of disease incidence in Costa Rica and Panama has allowed for prediction of future sites of decline (Lips 2006). Disease progression may have significant implications for worldwide amphibian species diversity as up to half of all species live in neotropical regions that environmental modeling has suggested could be a suitable niche for Bd (Ron 2005).

It is unclear if Bd is a novel pathogen that has recently been introduced to naïve populations or an endemic pathogen that has emerged because of environmental or other co-factors (Rachowicz 2005). It may be that both circumstances exist depending on geographic location. Preliminary genetic information obtained from isolates originating from several continents has suggested that Bd is a recently emerged clone possibly consistent with an introduced novel pathogen (Morehouse 2003). Research on the means of introduction of Bd to new locations has focused on international movement of amphibians for purposes such as food, laboratory research and the pet trade. In particular, the African clawed frog (*Xenopus laevis*) and the bullfrog (*Rana catesbeiana*) are species that have been widely moved or introduced worldwide and are good potential reservoir hosts for Bd because they carry infection without significant clinical signs (Weldon 2004; Daszak 2004). The occurrence of Bd-associated mortality events at lower temperatures (within preferred temperature ranges for Bd), suggests that environmental co-factors may play a role in mortality events resulting from either recent introduction of Bd to a region or by exacerbating endemic infections (Berger 2004; Piotrowski 2004). Stable endemic Bd infection of populations has been documented following catastrophic declines presumed to have been due to introduced Bd infection (Retallick 2004) as well as in populations without documented declines (Ouellet 2005).

Pathology and Pathogenesis

Lesions of chytridiomycosis are limited to keratinizing epithelium in the skin of postmetamorphic animals and the mouthparts (toothrows and jaw sheaths) of tadpoles (Berger 1998; Pessier 1999; Rachowicz 2004). Dissemination to deeper portions of the skin or to viscera does not occur. Lesions consist of varying degrees of epidermal hyperplasia and hyperkeratosis with intralesional thalli characteristic of Bd (Figure 1). The keratinized layers (*stratum corneum*) of amphibian skin are usually very thin (Figure 1) and hyperkeratosis can be overlooked if using criteria established for other species. Associated inflammatory cell infiltrates are an inconsistent finding and when observed are usually in association with severe or chronic infections or in cases with secondary bacterial or fungal infection. Secondary infections are common presumably because environmental bacteria and fungi become trapped in excessive keratin layers or within empty thalli of Bd that have expelled zoospores. The severity and distribution of lesions can range from relatively minimal focal lesions in subclinically infected animals (Hanselmann 2004) to severe multifocally-extensive to diffuse lesions that are considered to be clinically significant.

There are characteristic features of Bd thalli that aid in identification in cytologic preparations or histologic section. The spherical thalli, which are intracellular in superficial keratinocytes, range from approximately 7-20 microns in diameter and mature thalli (zoosporangia) may contain discrete 1-2 micron basophilic zoospores. Empty thalli that have discharged their zoospores are very common and should be distinguished from cross sections of fungal hyphae or ducts of cutaneous glands. Flask-shaped thalli with prominent discharge papillae (discharge tubes) can usually be found in most heavy infections (Figure 2). Colonial thalli have evidence of fine internal septation and are best appreciated in empty thalli or in Gomori methenamine silver (GMS) stained sections (Figure 2). An inconsistent, but sometimes helpful, finding in GMS stained sections are thin root-like extensions from thalli termed rhizoids (Figure 2).

The mechanism by which Bd causes death of susceptible animals is still unclear. Disruption of normal skin function, especially in regard to water absorption and electrolyte balance, and secretion of a mycotoxin are the most frequently cited hypotheses. Some clinically affected animals show evidence of dehydration and hemoconcentration and this may provide support for disruption of skin function (Green 2005). Preliminary evidence of death in *Bufo boreas* tadpoles exposed to cultures of Bd could provide support for the role of a mycotoxin (Blaustein 2005). There is evidence for both species and age-related differences in susceptibility to clinically significant infections (Davidson 2003; Hanselmann 2004; Lamirande 2002).

Transmission of Bd infection is via the motile flagellated zoospores and can occur by direct contact between animals or by contact with water or substrates used in housing affected animals. Extension of infection from the keratinized mouthparts of tadpoles can occur as the tadpoles metamorphose and develop a keratinized epidermis (Lamirande 2002;Rachowicz 2004).

Clinical Signs

Clinical signs of chytridiomycosis can be variable and range from unexpected death without premonitory signs to cases with evidence of significant skin disease. The most common cutaneous signs of chytridiomycosis are excessive shedding (“sloughing”) of skin, rough or granular changes in skin texture, and brown to red (hyperemia) skin discoloration. Findings are most often distributed on the ventral body and feet of terrestrial animals, but can be diffuse in totally aquatic species. Hyperemia and other features such as cutaneous ulceration are more common in animals with secondary bacterial, fungal, or water mold (Oomycete) infections. In these instances, chytridiomycosis should be distinguished from other potential causes of “red leg” syndrome including bacterial septicemia and iridovirus infection.

Other clinical signs that may be observed include postural changes, in which animals hold their legs away from the body apparently to avoid contact with substrate, avoidance of or increased preference for water, anorexia, lethargy, and neurologic signs such as loss of righting reflex.

Tadpoles infected with Bd are usually asymptomatic and may serve as reservoirs of infection for postmetamorphic animals. Detailed gross examination of the keratinized mouthparts may show areas of depigmentation that should be distinguished from other potential causes of mouthpart abnormality including chemical exposure and low environmental temperature (Rachowicz 2004). Reduced body mass of infected tadpoles and deaths of some individuals in acute exposure studies have been reported for selected species (Parris 2004; Blaustein 2005).

Diagnosis

Diagnosis of infection with Bd has been described using both morphologic (cytology and histopathology) and molecular techniques (polymerase chain reaction). Routine fungal culture is not helpful since Bd requires specialized techniques for isolation (Longcore 1999). Selection of a diagnostic method is dependant on the purpose of the investigation, for instance surveys of wild populations for presence, absence, or prevalence of Bd infection increasingly rely on molecular methods, whereas for investigation of mortality events, histopathology which allows for assessment of the clinical significance of lesions (and can exclude other disease entities) is preferable.

Diagnosis using cytology or histopathology is by demonstration of characteristic thalli of Bd within the cytoplasm of keratinocytes (see Pathology and Pathogenesis for morphologic characteristics of Bd thalli). For rapid diagnosis of heavy Bd infection in a clinical setting, cytology or wet mounts can be useful. These are not appropriately sensitive techniques for screening wild populations or animals in quarantine and may not detect all clinical cases. Samples are obtained by recovering shed skin fragments or by gentle skin scraping using a toothpick or the end of a cotton-tipped applicator. Samples are air-dried on slides, stained using a rapid hematologic dye and examined under oil immersion (Nichols 2001; Pessier 2002). Diagnosis should only be made if unequivocal Bd thalli are observed because yeasts and fragments of Oomycete water molds can occasionally be confused for degenerate thalli.

Diagnosis by histopathology can be made from both clinically obtained and necropsy samples. Immunohistochemistry using polyclonal antibodies has been described as an aid in histologic diagnosis, however, for most clinically significant infections diagnosis based on morphologic criteria alone will be sufficient (Van Ells, 2003). A potentially useful and non-invasive clinical sample is to fix fragments of shedding (sloughing) skin in formalin for histologic examination. This technique occasionally provides better morphologic detail of Bd thalli (especially empty thalli) than that obtained by cytologic examination of skin fragments. Histologic examination of toe clips has been described for wild frogs, but this technique may be too invasive for clinical utility. At necropsy, routine collection of multiple skin sections for histopathology to include the ventral pelvic ("drink patch") region, ventral legs, and feet are suggested both for surveillance of amphibian collections and for diagnosis of suspected clinical cases. For very small animals such as dendrobatids, this can be accomplished by processing multiple whole body sections (including feet) following decalcification.

Detection of Bd DNA in skin swabs or scrapings by either conventional or real-time Taqman polymerase chain reaction (PCR) has been a recent technical advance (Annis 2004; Boyle 2004). These methods will be especially helpful for determining incidence and prevalence of infection in wild populations, screening of animals both in quarantine and prior to release to the wild from captive breeding programs, and for clinical diagnostics. Although the PCR methods are extraordinarily sensitive, it should be noted that early or subclinical Bd infections can be unevenly distributed and empty thalli (no longer containing DNA) are common, thus the possibility of false-negatives as a result of sampling should be considered when interpreting results. Ideally, swabs or scrapings submitted for PCR should include material from more than one location on the ventral body and feet. In the United States, PCR for Bd is commercially available through Pisces Molecular, Boulder, CO (303-546-9300; jwood@pisces-molecular.com).

Disease Control and Treatment

Control of chytridiomycosis in amphibian colonies includes disinfection of enclosures and implementation of husbandry practices that prevent cross-contamination of enclosures with water or substrate material. The infectious zoospores are sensitive to desiccation and to date, no resting stages resistant to drying have been identified. Hence the primary means of transmission in animal groups is by direct animal to animal contact or contact with water or moist substrates used in housing infected animals. Bd can persist in tap water and sterilized lake water for several weeks, several months in sterilized moist river sand, and up to 3 hours on avian feathers (Johnson 2003b; Johnson 2005). Most commonly used disinfectants including quaternary ammonium compounds and sodium hypochlorite (bleach) are effective in killing Bd as is heat (47^0 C for 30 minutes), however, UV light is relatively ineffective (Johnson 2003a).

Treatment for chytridiomycosis has been described using non-specific chemical agents, specific anti-fungal agents and elevation of environmental temperature. Topical treatment such as immersion baths, rather than systemic treatment, is suggested because of the superficial cutaneous location of the infection. If there is no prior experience using a specific drug in a particular amphibian species or age-group, consideration could be given to treatment of sentinel animals before treatment of large groups. For individual animals with severe disease supportive care including fluid therapy for dehydration and antibiotics to control secondary bacterial infections may be helpful. Treatment has been successful both for individual animals as well as amphibian colonies, however, there are concerns that treatment alone cannot guarantee clearance of Bd from all groups of frogs (Harkewicz 2005). Experimental studies on the clearance of Bd following treatment as well as studies that examine combinations of treatments such as antifungal baths and increased environmental temperature are warranted.

Treatment using a bath of 0.01% itraconazole has been described experimentally (Nichols 2000; Lamirande 2002) and subsequently applied to a variety of species in zoological institutions and conservation programs. The bath is prepared by diluting the commercially available 1% itraconazole solution (or a compounded suspension) in 0.6% saline or amphibian Ringer’s solution (Wright 2001). Animals are placed in a shallow bath for 5 minutes daily for up to 11 days. The bath should be periodically agitated to ensure that the entire skin surface is treated. Itraconazole should be avoided in tadpoles and used with caution in very young postmetamorphic animals because treatment associated deaths have been observed in both Australia and the United States. It is unknown if these deaths are attributable to the drug itself or to other components of the itraconazole formulation. Use of fluconazole in tadpoles did not appear to have toxic effects (Marantelli 2001).

Treatment of chytridiomycosis in African clawed frogs (*Xenopus tropicalis*) was accomplished using a solution of 25 ppm formalin and 0.1mg/L malachite green for 24 hours repeated every other day for a total of 4 treatments (Parker 2002). This treatment could be considered for use in other aquatic species as long as potential adverse effects of both formalin and malachite green are taken into account (Wright 2001).

The preference of Bd for lower temperatures (optimum growth at $17\text{-}25^0$ C; Piotrowski 2004) has the potential to be exploited as a primary or adjunctive treatment in species that can tolerate higher environmental temperatures. Animals held at 37^0 C for less than 16 hours appeared to be cleared of Bd infection (Woodhams 2003) and experimental animals housed at 27^0 C had apparent elimination of infection by 98 days post infection (Berger 2004). Use of elevated temperatures in the treatment of naturally occurring infections has not been reported.

Treatment of entire groups of captive animals can be considered because of species salvage efforts that bring infected wild animals into captivity or because of repeated outbreaks in closed colonies that presumably occur because of subclinically infected carrier animals within a group. In two separate captive breeding groups of Wyoming toads (*Bufo baxteri*) repeated outbreaks occurred over a period of several years and chytridiomycosis was the major cause of mortality. Colony-wide treatment using a combination of itraconazole baths and disinfection of enclosures was instituted and no chytridiomycosis-associated deaths have been documented over a subsequent 3- year period using aggressive clinical and necropsy surveillance.

Quarantine and Reintroduction Programs

General considerations for amphibian quarantine have been described and are available online (Amphibian Diseases Web Page **www.jcu.edu.au/school/phtm/PHTM/frogs/ampdis**). For amphibians entering into quarantine, an initial consideration is the health history of the originating collection, which ideally would include thorough clinical and necropsy surveillance for infectious diseases. Such surveillance data is usually not available for animals obtained from dealers or that have been acquired from the wild. Complete necropsies, including histopathology, should be performed on all animals that die in quarantine and can provide a comprehensive measure of health status for animals destined to enter an animal collection. Histopathology for chytridiomycosis should include multiple skin sections as noted previously, and may be helpful even in autolyzed specimens. If available, incoming amphibians (or subsets of incoming animals in large groups) can be screened for Bd by PCR of skin scrapings or skin swabs. Prophylactic antifungal treatment of entire groups can be considered if animals are coming from high-risk situations or if Bd positive animals are identified by PCR or histopathology.

Similar measures are suggested for prevention and control of Bd infections in animals involved in captive breeding and re-introduction programs. Ideally, breeding groups of amphibians producing offspring for later release into the wild should be maintained in a state of permanent quarantine in order to minimize the possibility of introduced infectious agents. Health surveillance of breeding groups to include necropsy and histopathology of all animals that die should be part of the standard operating procedures. If chytridiomycosis is identified prophylactic group treatment can be initiated followed by PCR and necropsy surveillance of the group for any subsequent infections. Animals from groups with identified Bd infections should not be used for releases to the wild until long-term (at least one year) group surveillance suggests that infection has been eliminated. Screening by PCR of a subset of animals destined for release is an additional option, but may not always be economically feasible because of the large numbers of animals involved in amphibian release programs. A significant concern for many release programs is not Bd infection in animals destined for release, but instead involves pre-existing Bd infection in free-ranging animals already present at release sites.

Amphibian Disease Web Site

The Amphibian Diseases Home Page (**www.jcu.edu.au/school/phtm/PHTM/frogs/ampdis.htm**) is a very useful web site with information on chytridiomycosis including published articles, diagnostic and quarantine protocols, and a comprehensive bibliography of amphibian diseases.

References

1. Annis, S.L., Dastoor, F.P., Ziel, H., Daszak, P., Longcore, J.E. 2004. A DNA-based assay identifies *Batrachochytrium dendrobatidis* in amphibians. J Wildl Dis 40(3): 420-428.
2. Berger, L., Speare, R., Dazsak, P., Green, D.E., Cunningham, A.A., Goggin, C.L., Slocombe, R., Ragan, M.A., Hyatt, A.D., McDonald, K.R., Hines, H.B., Lips, K.R., Marantelli, G., Parkes H. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proc Natl Acad Sci USA 95: 9031-9036.
3. Berger, L., Speare, R., Hines, H.B., Marantelli, G., Hyatt, A.D., McDonald, K.R., Skerratt, L.F., Olsen, V., Clarke, J.M., Gillespie, G., Mahony, M., Sheppard, N., Williams, C., Tyler, M.J. 2004. Effect of season and temperature on mortality in amphibians due to chytridiomycosis. Aust Vet J 82(7): 434-439.
4. Bosch, J., Martinez-Solano, I., Garcia-Paris, M. 2001. Evidence of a chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. Biol Conserv 97: 331-337.
5. Blaustein, A.R., Romansic, J.M., Scheessele, E.A., Han, B.A., Pessier, A.P., Longcore, J.E. 2005. Interspecific variation in susceptibility of frog tadpoles to the pathogenic fungus *Batrachochytrium dendrobatidis*. Conserv Biol 19(5): 1460-1468.
6. Boyle, D.G., Boyle, D.B., Olsen, V., Morgan, J.A.T., Hyatt, A.D. 2004. Rapid quantitative detection of chytridiomycosis (*Batrachochytrium dendrobatidis*) in amphibian samples using real-time Taqman PCR assay. Dis Aquat Org 60: 141-148.
7. Bradley, G.A., Rosen, P.C., Sredl, M.J., Jones, T.R., Longcore, J.E. 2002. Chytridiomycosis in native Arizona frogs. J Wildl Dis 38: 206-212.
8. Daszak, P., Berger, L., Cunningham, A.A., Hyatt, A.D., Green, D.E., Speare, R. 1999. Emerging infectious diseases and amphibian population declines. Emerg Infect Dis 5(6): 735-748.
9. Daszak, P., Strieby, A., Cunningham, A.A., Longcore, J.E., Brown, C.C., Porter, D. 2004. Experimental evidence that the bullfrog (*Rana catesbeiana*) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetological Journal 14: 201-207.
10. Davidson, E.W., Parris, M., Collins, J.P., Longcore, J.E., Pessier, A.P., Brunner, J. 2003. Pathogenicity and transmission of chytridiomycosis in tiger salamanders (*Ambystoma tigrinum*). Copeia 2003(3): 601-607.
11. Green, D.E., Converse, K.A., Schrader, A.K. 2002. Epizootiology of sixty-four amphibian mortality events in the USA, 1996-2001. Ann NY Acad Sci 969: 323-339.

12. Green, D.E., Muths, E. 2005. Health evaluation of amphibians in and near Rocky Mountain National Park (Colorado, USA). Alytes 22(3-4): 109-129.
13. Hanselmann, R., Rodriguez, A., Lampo, M., Fajardo-Ramos, L., Aguirre, A., Kilpatrick, A.M., Rodriguez, J.P., Daszak, P. 2004. Presence of an emerging pathogen of amphibians in introduced bullfrogs (*Rana catesbeiana*) in Venezuela. Biol Conserv 120(1): 115-119.
14. Harkewicz, K., Pessier, A.P., Rollins-Smith, L.A., Speare, R., Weldon, C. 2005. Amphibian chytridiomycosis roundtable. J Herpe Med Surg 15(3):28-40.
15. Johnson, M.L., Berger, L., Phillips, L., Speare, R. 2003a. Fungicidal effects of chemical disinfectants, UV light, dessication and heat on the amphibian chytrid *Batrachochytrium dendrobatidis.* Dis Aquat Org 57: 255-260.
16. Johnson, M.L., Speare, R. 2003b. Survival of *Batrachochytrium dendrobatidis* in water: Quarantine and disease control implications. Emerg Infect Dis 9(8): 922-925.
17. Johnson, M.L., Speare, R. 2005. Possible modes of dissemination of the amphibian chytrid *Batrachochytrium dendrobatidis* in the environment. Dis Aquat Org 65:181-186.
18. Lamirande, E.W., Nichols, D.K. 2002. Effects of host age on susceptibility to chytridiomycosis in blue-and-yellow poison dart frogs (*Dendrobates tinctorius*). Proc Sixth Int Sympos Path Amphib Rept, St. Paul, MN, pp. 3-16.
19. Lips, K.R., Reeve, J.D., Witters, L.R. 2003. Ecological traits predicting amphibian population declines in Central America. Conserv Biol 17(4): 1078-1088.
20. Lips, K.R., Brem, F., Brenes, R., Reeve, J.D., Alford, R.A., Voyles, J., Carey, C., Livo, L., Pessier, A.P., Collins, J.P. 2006. Emerging infectious disease and the loss of biodiversity in a neotropical amphibian community. Proc Natl Acad Sci USA 103: 3165-3170
21. Longcore, J.E., Pessier, A.P., Nichols, D.K. 1999. *Batrachochytrium dendrobatidis* gen. et sp. nov., a chytrid pathogenic to amphibians. Mycologia 91(2): 219-227.
22. Marantelli, G., Berger, L., McInnes, K. 2001. Investigations into the treatment of *Batrachochytrium* in frogs and tadpoles. Getting the Jump on Amphibian Disease Conference, Cairns, Australia, pp. 27.
23. Morehouse, E.A., James, T.Y., Ganley, A.R.D., Vilgalys, R., Berger, L., Murphy P.J., Longcore, J.E. 2003. Multilocus sequence typing suggests the chytrid pathogen of amphibians is a recently emerged clone. Molec Ecol 12: 395-403.
24. Muths, E., Corn, P.S., Pessier, A.P., Green, D.E. 2003. Evidence for disease-related amphibian decline in Colorado. Biol Conserv 110: 357-365.
25. Mylniczenko, N.D. 2003. Caecilians (Gymniophona, Caecilia). In Fowler, M.E., Miller, R.E. eds. Zoo and Wild Animal Medicine, Vol. 5. Philadelphia, W.B. Saunders, pp. 40-45.
26. Nichols, D.K., Lamirande, E.W., Pessier, A.P. 2000. Experimental transmission and treatment of cutaneous chytridiomycosis in poison dart frogs (*Dendrobates azureus* and *Dendrobates tinctorius*). Joint Proc Am Assoc Zoo Vet and Int Assoc Aquat An Med, New Orleans, LA, pp. 42-44.

27. Nichols, D.K., Lamirande, E.W., Pessier, A.P., Longcore, J.E. 2001. Experimental transmission of cutaneous chytridiomycosis in dendrobatid frogs. J Wildl Dis 37:1-11.
28. Ouellet, M., Mikaelian, I., Pauli, B.D., Rodrigue, J., Green, D.M. 2005. Evidence of widespread chytrid infection in North American amphibian populations. Conserv Biol 19(5): 1431-1440.
29. Parker, J.M., Mikaelian, I., Hahn, N., Diggs, H.E. 2002. Clinical diagnosis and treatment of epidermal chytridiomycosis in African clawed frogs (*Xenopus tropicalis*). Comp Med 52(3):265-268.
30. Parris, M.J., Baud, D.R. 2004. Interactive effects of a heavy metal and chytridiomycosis on gray treefrog larvae (*Hyla chrysoscelis*). Copeia 2004(2):344-350.
31. Pessier, A.P., Nichols, D.K., Longcore, J.E., Fuller, M.S. 1999. Cutaneous chytridiomycosis in poison dart frogs (*Dendrobates* spp.) and White's tree frogs (*Litoria caerulea*). J Vet Diagn Invest 11: 194-199.
32. Pessier, A.P. 2002. An overview of amphibian skin disease. Semin Avian Exotic Pet Med 11(3): 162-174.
33. Piotrowski, J.S., Annis, S.L., Longcore, J.E. 2004. Physiology of *Batrachochytrium dendrobatidis,* a chytrid pathogen of amphibians. Mycologia 96(1): 9-15.
34. Stuart, S.N., Chanson J.S., Cox, N.A., Young B.E., Rodrigues, A.S.L., Fischman D.L., Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306: 1783-1786.
35. Rachowicz, L.J., Hero, J., Alford, R.A., Taylor, J.W., Morgan, J.A.T., Vrendenberg, V.T., Collins, J.P., Briggs, C.J. 2005. The novel and endemic pathogen hypotheses: Competing explanations for the origin of emerging infectious diseases of wildlife. Conserv Biol 19(5): 1441-1448.
36. Rachowicz, L.J., Vrendenberg, V. T. 2004. Transmission of *Batrachochytrium dendrobatidis* within and between amphibian life stages. Dis Aquat Org 61: 75-83.
37. Retallick, R.W.R., McCallum, H., Speare, R. 2004. Endemic infection of the amphibian chytrid fungus in a frog community post-decline. PloS Biology 2(11): 1965-1971.
38. Ron, S.R. 2005. Predicting the distribution of the amphibian pathogen *Batrachochytrium dendrobatidis* in the new world. Biotropica 37(2): 209-221.
39. Van Ells, T., Stanton, J., Strieby, A., Daszak, P., Hyatt, A.D., Brown, C. 2003. Use of immunohistochemistry to diagnose chytridiomycosis in dyeing poison dart frogs (*Dendrobates tinctorius*). J Wildl Dis 39(3): 742-745.
40. Weldon, C., du Preez, L.H., Hyatt A.D., Muller, R., Speare, R. 2004. Origin of the amphibian chytrid fungus. Emerg Infect Dis 10(12): 2100-2105.
41. Woodhams, D.C., Alford, R.A., Marantelli, G. 2003. Emerging disease of amphibians cured by elevated body temperature. Dis Aquat Org 55: 65-67.
42. Woodhams, D.C., Alford, R.A. 2005. Ecology of chytridiomycosis in rainforest stream frog assemblages of tropical Queensland. Conserv Biol 19(5): 1449-1459.

43. Wright, K.M., Whitaker, B.R. 2001. Pharmacotherapeutics. In Wright, K.M., Whitaker, B.R. eds. Amphibian Medicine and Captive Husbandry. Malabar, FL, Kreiger Publishing, pp. 309-330.

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ECOHEALTH

Spread of Chytridiomycosis Has Caused the Rapid Global Decline and Extinction of Frogs

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Abstract: The global emergence and spread of the pathogenic, virulent, and highly transmissible fungus *Batrachochytrium dendrobatidis*, resulting in the disease chytridiomycosis, has caused the decline or extinction of up to about 200 species of frogs. Key postulates for this theory have been completely or partially fulfilled. In the absence of supportive evidence for alternative theories despite decades of research, it is important for the scientific community and conservation agencies to recognize and manage the threat of chytridiomycosis to remaining species of frogs, especially those that are naive to the pathogen. The impact of chytridiomycosis on frogs is the most spectacular loss of vertebrate biodiversity due to disease in recorded history.

Keywords: chytridiomycosis, *Batrachochytrium dendrobatidis*, decline, extinction, frogs, amphibians, postulates, global

INTRODUCTION

Amphibian populations have recently undergone declines and extinctions on a global scale (Stuart et al., 2004). Nine species have become extinct since 1980, and 113 more are possibly extinct. Four hundred and thirty-five species have demonstrated rapid declines since 1980. The declines of 233 species are attributed to overexploitation or habitat loss (Stuart et al., 2004). Of the remaining 202 rapidly declining species, and some populations of 5 species experiencing habitat loss, no cause has been attributed—these declines are labeled ‘‘enigmatic’’ by Stuart et al. (2004). Species affected by enigmatic declines are mostly stream-associated frogs at medium to high altitude, in protected forested sites in the tropics of Central and South America and northern Australia. Stuart et al. (2004) list the amphibian chytrid fungus *Batrachochytrium dendrobatidis (Bd)* as a commonly cited cause of declines of frogs but do not consider whether it is the primary cause of ‘‘enigmatic’’ declines. Here we present the evidence that the emergence and spread of this virulent skin pathogen, *Bd*, which causes chytridiomycosis, is by far the most likely primary cause of most of these ‘‘enigmatic’’ declines of frogs.

Because dead frogs are hard to find and are scavenged or decompose quickly, mass mortality events have been

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insidious and have largely gone undetected. Rapid declines (i.e., <1 year) can only be caused by the death of adults, and the only plausible causes of this in undisturbed habitats are a toxin, abnormal environmental change, or an infectious pathogen (Laurance et al., 1996). Discriminating among these possible causes has been difficult because investigations of the causes of declines usually start after the event, and no dead or dying frogs are observed or collected for necropsy. No evidence of a globally disseminated toxin has been presented and the current environmental changes in tropical areas (where most declines have occurred) have occurred previously and have not caused rapid declines (Alexander and Eischeid, 2001). By extrapolating what is known from a few well-studied sites during declines in Australia, Central America, North America, and Spain (Berger et al., 1998; Bosch et al., 2001; Muths et al., 2003; Lips et al., 2006; Schloegel et al., 2006) to sites with similar patterns of decline (Bell et al., 2004; La Marca et al., 2005; Scherer et al., 2005) and using the increasing knowledge of the biology of *Bd*, we show that chytridiomycosis is the only explanation, for which supporting evidence is available, for these global "enigmatic" declines and disappearances of frog populations and species. We also show that the most parsimonious explanation with supporting evidence for the emergence of chytridiomycosis is the introduction and spread of *Bd* among naive populations of frogs (Laurance et al., 1996; Berger et al., 1999; Daszak et al., 1999; Weldon et al., 2004).

Koch's postulates have been used in determining whether infectious agents cause disease in individuals (Evans, 1976). These traditional postulates have been conclusively satisfied for *Bd*, and studies have shown that it is highly pathogenic and virulent in individuals of declining species; experimental work shows that pure cultures isolated from sick and dying frogs cause fatal disease in otherwise healthy frogs (Lamirande and Nichols, 2002; Woodhams et al., 2003; Berger et al., 2004; Carey et al., 2006). Here we propose two mutually exclusive theoretical scenarios by which an infectious pathogen could cause global population declines, and propose criteria for differentiating between them. This framework can be applied to populations that have suddenly declined, even if mass mortality has not been detected. This is an important advance for conservation medicine, as traditional veterinary epidemiological approaches do not take into account the difficulties associated with the investigation of wildlife diseases (Wobeser, 1994).

Framework

We propose two alternative theoretical scenarios for how an infectious pathogen can cause severe population declines globally and drive species to extinction, based on current understanding of host–pathogen interactions. These explanations were first proposed for chytridiomycosis by Berger et al. (1998).

1. Distributional spread of a highly pathogenic, virulent, transmissible pathogen, leading to high mortality and failure of recruitment of the next generation in naive populations of susceptible species (definition of pathogenic: capable of causing disease; definition of virulent: causes severe disease). This has been named the "novel pathogen hypothesis" (Rachowicz et al., 2005). This is perhaps a misleading name to some, as while the pathogen *Bd* was unknown to science and is new to host populations, it is likely that it has existed for a long time in obscurity. A better name would be the "spreading pathogen hypothesis." This is the main reason for disease emergence and the only reason for pandemics to date (Morse, 1995). Some of the numerous examples of pandemics due to disease spread are the human influenza pandemics of the 20th century, the AIDS pandemic, the SARS pandemic, the canine parvoviral enteritis pandemic, crayfish plague, and recently the H5N1 avian influenza pandemic.
2. Abnormal environmental change (e.g., climate change, increased UV-B radiation, pollution) that results in an already widespread pathogen becoming highly pathogenic, virulent, and transmissible, resulting in high mortality and failure of recruitment of the next generation (the pathogen may already have some of these characteristics but not all prior to the environmental change). This has been named the "emerging endemic hypothesis" (Rachowicz et al., 2005). This scenario has not occurred on a global scale previously (Morse, 1995) and is a theoretical hypothesis based on extrapolation from the reasons for localized emergence of endemic pathogens. It is also a less parsimonious hypothesis.

There have been several papers discussing the strengths and weaknesses of the evidence for these scenarios (Daszak et al., 2003; McCallum, 2005; Rachowicz et al., 2005). Daszak et al. (2003) review the evidence and conclude that chytridiomycosis has caused amphibian population declines and that anthropogenic introduction appears to be a factor in its emergence. McCallum (2005) states that the evidence for chytridiomycosis causing widespread amphibian declines is not conclusive and argues for the collection of more data on the biology of *Bd* which affects host population dynamics. He states that there is insufficient evidence to reject either of the above scenarios but does not discuss the evidence. Rachowicz et al. (2005) does not conclude that *Bd* is a novel pathogen and states that conclusive genetic evidence is needed before accepting this hypothesis. The scientific philosophy used in these latter two papers is called "refutationism" and is based on trying to disprove a hypothesis based on a particular line of evidence that tests the hypothesis. While we agree that it is important to test hypotheses, it is more important that action is taken to conserve species before the outcome of these rigorous tests are known.

Conservation has similar goals to medicine in that it tries to understand natural phenomenon quickly and manage them. Therefore, we have adopted a medical approach to determine causation (that includes inductive and deductive reasoning), and it is used successfully to determine likely causes of outbreaks leading to life-saving interventions (Dohoo et al., 2003). For example, John Snow determined the origin and method of transmission of cholera and suggested management techniques long before the discovery of the causal pathogen (Snow, 1860). This approach makes decisions and takes action based on the combined weight of all available evidence (a mental Bayesian approach) rather than waiting for proof of a hypothesis by a particular method. This example also highlights the importance of understanding the natural history of disease in order to determine causation, and the danger in relying on one line of evidence such as ecological correlations to test a hypothesis (Eyler, 2001). Therefore, we considered the approaches of multiple disciplines rather than relying solely on one, to provide a set of empirically testable postulates, which must be adequately satisfied before either scenario can be confidently accepted. These postulates are derived from current understanding of the factors which drive emergence of infectious disease, and they determine the effect that a disease has on host population dynamics, and traditional postulates that show causation of disease (Evans, 1976; Morse, 1995; Hudson et al., 2002). We conclude that the data for some evidence is not conclusive. Exceptions are likely and further research is crucial; however, there is currently enough combined evidence available to at least either strongly support or accept one hypothesis so that appropriate conservation management strategies can be undertaken (Australian Government Department of the Environment and Heritage, 2004).

Postulated Requirements for Scenario 1: Spreading Pathogen Hypothesis

a. The pathogen is capable of causing population decline and extinction. It is therefore highly pathogenic, virulent, and transmissible. (Disease modeling demonstrates that these are key factors for pathogens causing population decline and extinction [Anderson and May, 1979]. Infectious organisms may experience trade-offs between virulence and transmission that prevents them from causing extinction [McCallum and Dobson, 1995].)
b. The pathogen is spreading. Therefore, the declines and the pathogen show temporal–spatial patterns of spread, and the pathogen is highly conserved genetically due to its recent rapid spread. The pathogen also has at least one source from which it has emerged. (The spread of pathogens is the main reason for disease emergence [Morse, 1995]. Introduced pathogens may also be highly pathogenic and virulent because the host population is naive and has not undergone selection for resistance to them [Fenner and Ratcliffe, 1965].)
c. The pathogen is present during declines and mass mortality events and appears to be causing the mortality based on its epidemiology and pathogenesis. (This is the key factor that links the pathogen to the decline event [Wobeser, 1994].)

Evidence Bearing on Postulates for Scenario 1

a. *Bd* is highly pathogenic and virulent in many frog species experimentally; even initial low doses (e.g., 100 zoospores) have caused the rapid onset of 100% mortality (Berger et al., 1999, 2004; Woodhams et al., 2003; Carey et al., 2006). However, some species are resistant or developing resistance, and some populations of susceptible species, which live in adverse environmental conditions for *Bd*, are protected (Ardipradja, 2001; Daszak et al., 2004; Australian Government Department of the Environment and Heritage, 2004; Retallick et al., 2004; Weldon et al., 2004; Garner et al., 2005; McDonald et al., 2005; Pounds et al., 2006).

   Bd is highly transmissible given that it has a life-cycle stage that survives in water (Longcore et al., 1999). It can also survive on a wide range of larval and adult amphibian species at low intensities of infection without causing mortality (McDonald et al., 2005; Hanselmann et al., 2005; Woodhams and Alford, 2005). These animals can act as reservoirs for transmission when host densities of vulnerable species are low, enabling *Bd* to drive species to extinction. In addition, the following combined evidence suggests *Bd* survives in the environment, which would further facilitate transmission when host densities are low by providing additional reservoirs of infection. *Bd* may survive in sterile environments for periods of up to 2 months, and it has been detected by PCR in the environment during mass mortality events (Johnson and Speare, 2003; Lips et al., 2006).

b. Studies of archived museum specimens and/or of recent mortality events suggest that *Bd* first appeared in amphibian populations immediately prior to their declines in USA (1974), Australia (1978), Costa Rica (1986), Panama (1996), and Venezuela (1986) (Berger et al., 1998; Lips, 1999; Speare et al., 2001; Bonaccorso et al., 2003; Puschendorf, 2003; Lips et al., 2006). Although data from most areas is not conclusive, the large study at El Copé, Panama, shows declines occurred when *Bd* appeared (Lips et al., 2006). Samples from 1566 amphibians collected from 2000 until July 2004 were negative when tested by PCR or histology. From September to December 2004, prevalence averaged 50% and the population declined abruptly (Lips et al., 2006). In Australia, the sudden appearance of Bd has been demonstrated by retrospective examination of museum specimens. The Australian epidemic appears to have commenced in southeast Queensland in the late 1970s (110 samples tested negative before 1978) before extending north and south along the coast (Australian Government Department of the Environment and Heritage, 2004). Chytridiomycosis in Western Australia was detected south of Perth in mid-1985 (612 earlier samples tested negative) and subsequently appeared to spread in all directions (Australian Government Department of the Environment and Heritage, 2004). After causing declines, *Bd* appears to settle into relatively stable endemic relationships in surviving frog populations, where it can always be detected in subsequent years in relatively small random samples of clinically healthy individuals, often at high prevalences (Berger et al., 2004; Retallick et al., 2004; McDonald et al., 2005). This is a similar sampling frame to museum specimens and gives confidence to the expectation that *Bd* will be present in museum specimens if it was present in the frog population at the time of collection. More work on archived collections of amphibians is needed to establish the historical distribution of *Bd*.

Bd is very highly conserved genetically and may be a clone given its extremely low genetic variation (Morehouse et al., 2003). Multilocus sequence typing was used to examine genetic diversity among fungal strains from North America, Panama, and Australia, and from frogs imported from Africa, and only five variable nucleotide positions were detected among 10 loci (5918 base pairs) (Morehouse et al., 2003). This is more consistent with *Bd* emerging recently and spreading globally than it is with long separate evolutionary histories of *Bd* in different continents. The genome of *Bd* has been sequenced, and examination of other parts of the genome of different geographical isolates should be undertaken to confirm its genetic homogeneity (Broad Institute of Harvard and MIT, 2006).

Declines associated with chytridiomycosis in Australia and the Americas have appeared to spread following relatively clear geographic and temporal patterns (Laurance et al., 1996; Berger et al., 1998; Lips, 1999). The emergence of chytridiomycosis in different continents and countries at different times is also consistent with geographic spread of the disease (Berger et al., 1998; Lips, 1999; Speare et al., 2001; Weldon et al., 2004; Lips et al., 2006). Therefore, priority should be given to the prevention of further spread of *Bd*.

Bd may have spread from southern African frogs. It has been found in samples collected in 1938 in South Africa, and the prevalence in African clawed frogs *(Xenopus laevis)* has remained stable since then, suggesting a stable endemic relationship between pathogen and host (Weldon et al., 2004). At present, this date precedes the earliest known dates for *Bd* in other continents by at least 23 years (Weldon et al., 2004; Ouellet et al., 2005). This suggests that *Bd* may have spread from Africa to most other continents in the 1960s and 1970s. This coincides with the general rapid growth in transportation of goods by air. Demonstration of higher levels of genetic diversity among isolates from southern Africa would support the hypothesis that *Bd* originated in that region.

c. Severe chytridiomycosis causing rapid death of frogs has been found associated with mass mortality of frog populations at the times of their declines in Australia, Panama, Costa Rica, and Spain (Berger et al., 1998; Lips, 1998, 1999; Bosch et al., 2001; Lips et al., 2006). The histopathological appearance of severe chytridiomycosis causing death during declines is identical to that seen in frogs that die from experimental infections (Berger et al., 1998). This pathological evidence is traditionally used in medicine to link the pathogen to the cause of mortality in individuals. Furthermore, severe chytridiomycosis has not been found in healthy wild frogs demonstrating high odds of death due to the severe form of the disease (Berger et al., 2004, unpublished observations).

The epidemiology of chytridiomycosis is consistent with the pattern of mortalities and enigmatic frog declines. *Bd* is much more virulent in adults compared with tadpoles, and it is adults that have been affected in mass mortality events. *Bd* is a waterborne pathogen mostly infecting frogs associated with permanent water, particularly streams, and it is these species of frogs that have experienced the most severe declines. *Bd* is pathogenic and virulent over a broad range of temperatures (12°–27°C) but has its greatest virulence at temperatures from 12°–23°C (Berger et al., 1998, 2004; Longcore et al., 1999; Woodhams et al., 2003; Carey et al., 2006). Pathogenicity and virulence decreases significantly as temperatures are raised above 27°C. It is frog species that occur at temperatures consistently below this upper threshold for *Bd*, which have been most affected (Berger et al., 1998, 2004; McDonald et al., 2005; Pounds et al., 2006). The lower temperature threshold for the virulence of *Bd* is not known, but temperate species have experienced less extinction compared with sub-tropical and tropical species of frogs. However, several determinants of disease and extinction other than temperature, such as size and distribution of populations, could account for these differences. In North America and Spain, *Bd* has its greatest effect on alpine species that experience freezing temperatures during winter (Bosch et al., 2001; Muths et al., 2003; Scherer et al., 2005).

Postulated Requirements for Scenario 2: Endemic Pathogen Hypothesis

a. The pathogen becomes highly pathogenic, virulent, and transmissible when abnormal environmental changes occur. (The pathogen may already have some of these characteristics but not all prior to the environmental change [Morse, 1995].)
b. The pathogen is endemic. Therefore, the declines and the pathogen do not show temporal–spatial patterns of spread unless the environmental change has a pattern of spread and the pathogen has geographical genetic variation consistent with genetic drift due to isolation and differences in selection pressure. The pathogen does not have a recent origin. (Typically, endemic pathogens may cause cyclical epidemics when immunity wanes or when particularly favorable environmental conditions for the pathogen occur [Thrushfield, 2005].)
c. Abnormal environmental changes occur immediately prior to and during pathogen outbreaks.
d. The pathogen continues to be present during declines and mass mortality events, and appears to be causing the mortality based on its epidemiology.

Evidence Bearing on Postulates for Scenario 2

a. There is strong evidence that the prevalence and virulence of *Bd* is determined by environmental conditions and is favored by moderate temperatures, such as those between 12° and 27°C, and environments with permanent water, particularly streams (Berger et al., 1998, 2004, in press; Longcore et al., 1999; Woodhams et al., 2003; Carey et al., 2006; Lips et al., 2006). These factors may determine the precise timing of increases in incidence of chytridiomycosis when it is endemic, such as the dramatic increase in prevalence in winter at low elevations in northern Queensland associated with temperatures dropping well below the upper threshold of tolerance for *Bd* (Berger et al., 1998, 2004; Woodhams et al., 2003; Retallick et al., 2004; McDonald et al., 2005; Woodhams and Alford, 2005). The environment will also affect the severity of an epidemic when *Bd* is introduced into a naive population. However, it will be a less important determinant compared with when the disease is endemic and selection for resistance has occurred (Thrusfield, 2005).

The above evidence shows that abnormal climatic conditions are not necessary for *Bd* to become highly pathogenic, virulent, and transmissible. In stark contrast, there is evidence to accept the opposing hypothesis, that environmental change is having a protective effect for frog populations threatened by chytridiomycosis. The survival of remnant populations of the green and golden bell frog *(Litoria aurea)* has occurred at some contaminated sites (e.g., a gold mine, copper smelter), suggesting that some pollutants may have antifungal effects on *Bd* and is currently being studied (Department of Environment and Conservation NSW, 2005; Berger et al., in press).

b. There is evidence that *Bd* has not been endemic for substantial periods before the onset of declines. Retrospective and contemporary surveys of specimens from areas where declines have occurred in Australia and Panama provide evidence to reject the hypothesis that chytridiomycosis was endemic prior to declines (Australian Government Department of the Environment and Heritage, 2004; Lips et al., 2006). There is also evidence of a temporal–spatial spread of declines and chytridiomycosis but no environmental change such as climate change or increased UV-B radiation associated with these patterns (Laurance et al., 1996; Berger et al., 1998; McDonald and Alford, 1999; Lips et al., 2006). As discussed for the first hypothesis, there is genetic evidence to suggest that geographically separated isolates share a very recent ancestor and therefore are recently introduced (Morehouse et al., 2003). As stated above, there is evidence that the pathogen may have originated recently from Africa.

c. There have been no consistent abnormal environmental changes immediately prior to and during enigmatic declines globally, which could have precipitated an unprecedented increase in pathogenicity, virulence, and transmissibility of *Bd* (Laurance et al., 1996; Alexander and Eischeid, 2001; Stuart et al., 2004). Pounds et al. (2006) present a correlation between warmer years associated with global warming and the last year a species of *Atelopus* was seen. There are alternate hypotheses regarding mechanisms for global warming as a key factor in driving extinctions due to chytridiomycosis: 1) that it promotes the spread of *Bd;* or 2) that it significantly increases its virulence.

   The plausible methods of spread of *Bd* are movement of infected hosts or contaminated fomites such as water either naturally or via trade. However, if one could show that *Bd* appeared in populations for the first time during unusually warm years, then it suggests a role for global warming in spreading *Bd*. Pounds et al. (2006) provide an explanation for the other hypothesis—how global warming could increase the virulence of *Bd*. They suggest that chytridiomycosis outbreaks are facilitated in warmer years that are due to global warming by higher minimum and lower maximum temperatures, which may be optimal for the disease. A way to provide evidence for this relationship would be to demonstrate that *Bd* had been present within a population for a short period previously and that outbreaks did not occur until warmer conditions due to global warming were present. One would still need to show that outbreaks were more severe due to the conditions created by global warming. This hypothesis is still dependent on the pathogen being introduced, as the annual climatic conditions associated with climate change, that have been suggested as being associated with outbreaks of chytridiomycosis, have occurred previously. The only change has been a long-term trend of more warmer-than-average years. If the pathogen was endemic and warmer years precipitated outbreaks, then one would expect an increased frequency of outbreaks, not novel epidemics.

   Unfortunately, the evidence of Pounds et al. (2006) is limited. They only provide a correlation of a warmer year with the last year a species is seen in the following year. This is not a correlation with the timing of declines due to chytridiomycosis, as the exact timing of declines cannot be determined from the data set. However, for the benefit of testing their hypothesis, let us assume that declines due to chytridiomycosis occur in a species in a warmer year. Data on the history of chytridiomycosis in these species is still needed to determine whether the timing of the declines is determined by increased virulence or spread of *Bd*. One could then try to determine the role of climate change. If it is not possible to obtain this data, then there are alternative methods for testing the role of climate change. One could test the effects of climate change on the virulence of *Bd* by studying frog populations where chytridiomycosis has become endemic. We are currently doing this within the tropics of Queensland. The prevalence of chytridiomycosis is largely dependent on seasonal temperature changes with consistently higher prevalence in winter compared with summer (range of odds ratios, 4.8–5.7) in the tropics (Retallick et al., 2004; McDonald et al., 2005; Woodhams and Alford, 2005) [Skerratt et al., unpublished observations]. The change in mean daily minimum and maximum temperatures between summer and winter in the Queensland tropics can be 6°–8°C. The important change is likely to be the drop in the mean daily maximum temperature from temperatures that are lethal to *Bd*, during summer, to temperatures that are within its preferred range in winter. This temperature change is a much greater change compared with the temperature changes seen with global warming, yet it only increases the prevalence of the disease and does not result in large declines of species susceptible to chytridiomycosis. Therefore, current data suggests that the changes seen with climate change do not explain the emergence of *Bd*.

In addition, the yearly average prevalence of chytridiomycosis has declined in populations where it is endemic in the Wet Tropics in Queensland over time despite drier than average years and global warming (McDonald et al., 2005). In cases where the timing of declines is known, they are not correlated with climate change (Laurance et al., 1996; McDonald and Alford, 1999; Bell et al., 2004; Scherer et al., 2005).

Lastly, given that the pathogenicity and virulence of *Bd* occurs over a broad experimental temperature range, then minor temperature changes associated with climate change are likely to have a minor effect unless they are strongly related to the spread of *Bd* (Berger et al., 1998, 2004; Carey et al., 2006). Because *Bd* is continuing to spread, it is possible to investigate the role of climate change. However, while it is important to consider the effects of climate change on chytridiomycosis, it is more important that the utmost is done to prevent the further spread of *Bd* into naive frog populations.

d. The evidence that the pathogen is present during declines and causes the mortality is accepted and is consistent with both hypotheses.

Discussion

We show that there is strong evidence to implicate chytridiomycosis caused by *Bd* as the major primary cause of extinctions and declines of anurans that have not been due to obvious causes, such as habitat loss described by Stuart et al. (2004). Further, we show that the evidence supports the hypothesis that these extinctions and declines are a result of the pathogenic, virulent, and highly transmissible amphibian chytrid fungus, *Bd*, spreading into naive populations. There is strong evidence against the theoretical and less parsimonious hypothesis that global environmental change has caused the emergence of *Bd* and that *Bd* was an endemic pathogen in declining populations. It is therefore important for conservation agencies to direct their major resources and energy towards research on the control and management of chytridiomycosis. In Australia, this has already occurred; *Bd* has been accepted by the federal government as a "Key Threatening Process" in 2002, and a draft Threat Abatement Plan was produced in 2004 and finalized in 2006 (Australian Government Department of the Environment and Heritage, 2004, 2006a, b). Recommendations in this plan cover quarantine issues, endangered species recovery projects, and future research. It has led to major funding (several million dollars) from the Australian Government Department of the Environment and Heritage, and the Australian Research Council for research and for the development of guidelines on determining the distribution, preventing the spread, and understanding the epidemiology and pathogenesis of chytridiomycosis. This work is ongoing but some of the research has been published in scientific journals, as government reports, and on the Amphibian Diseases Home Page (Speare et al., 2005; Speare, 2006; Berger et al., in press). Knowledge of the epidemiology and pathogenesis of *Bd* is essential in attempts to prevent further declines and in planning captive husbandry, selection for resistance, and reintroduction as part of species recovery projects. It is important for other nations to develop their own control plans.

Conservation agencies outside of Australia have been comparatively slow to recognize the threat of chytridiomycosis. It is now 10 years since an infectious disease was proposed as the cause of frog declines in Australia, and 8 years since the initial discovery of chytridiomycosis by Berger et al.(1998) as the cause of frog declines and extinction in Australia and Panama. We believe this slow response reflects a lack of recognition of the importance of disease in regulating wildlife populations by conservation science (Wilcox, 2006). While there has been a generally increasing theoretical interest in ecology of disease in free living populations over the past 30 years, there have been few empirical studies (Hudson et al., 2002).

There are old lessons that need to be re-learned from amphibian declines. One is that emerging diseases can cause rapid decline and extinction of species in pristine habitats. Diseases have caused population declines and have been associated with extinctions previously (Daszak et al., 2000). However, this is the first time that an emerging disease has been documented to cause the decline or extinction of hundreds of species not otherwise threatened. The threat of invasive plants and pests to conservation is well known. The fact that parasites, both macro- and micro-, could cause similar devastation is not a great leap of logic. Another lesson to be learned is that this pathogen has been able to emerge worldwide very quickly, causing widespread declines and extinctions. It appears very likely that one of the causes of this emergence is movement of the pathogen, probably aided by human transport. Globalization without adequate quarantine, surveillance, and parasite control programs will result in further outbreaks of disease in wildlife populations and loss of biodiversity. Finally, there is an obvious need for a global strategy to abate the threat of chytridiomycosis (Skerratt et al., 2006). At present, evidence suggests that there should be substantial effort directed towards preventing the spread of *Bd* into new geographic regions. Therefore, there is an urgent need to map the present and past global distribution of *Bd*, targeting large unsurveyed areas such as Asia and improving the biosecurity of frog populations found to be free of *Bd*. This will involve actions such as implementing quarantine and health screening protocols for amphibian trade.

There are two international bodies, the Office International des Epizooties (OIE) and the World Conservation Union (IUCN), which have interests and expertise in controlling diseases and conserving species, respectively. These bodies have started to develop strategies but need to work together to coordinate a global plan to control chytridiomycosis. The Amphibian Conservation Summit in Washington in 2005 called for major funding for research on chytridiomycosis (Mendelson et al., 2006). It suggested that regional diagnostic centers and rapid response teams be set up to deal with outbreaks. Chytridiomycosis was added to the list of wildlife diseases of concern of the OIE in 2001 (OIE Working Group on Wildlife Diseases, 2001–2005), and Williams et al. (2002) proposed that it be listed as a notifiable disease with consequent testing requirements for import and export of amphibians. This has not happened, but the OIE Working Group on Wildlife Diseases has sent a questionnaire to member countries each year, since 2002, asking whether chytridiomycosis is present or absent and the number of animals affected each year (OIE Working Group on Wildlife Diseases, 2001–2005). Guidelines for screening amphibians for diseases in translocation programs have been formulated by the Veterinary Specialist Group within the IUCN (Cunningham et al., 2001). The Aquatic Animal Health Standards Commission of the OIE, to enable it to address the issue of the spread of amphibian diseases, produced a questionnaire which was sent to Member Countries, in order to get more information on amphibian trade and amphibian health in different parts of the world; they have formed an ad hoc Group on Amphibian Diseases (OIE Fish Diseases Commission, 2002; OIE Aquatic Animal Health Standards Commission 2003, 2006). A forum on chytridiomycosis involving government and non-government organizations and individuals concerned with controlling the effects of disease on biodiversity, led by the OIE and IUCN, would facilitate international and national strategies and enable development of a rapid communication system of research results to inform and update policy.

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References

Alexander MA, Eischeid JK (2001) Climate variability in regions of amphibian declines. *Conservation Biology* 15:930–942

Anderson RM, May RM (1979) Population biology of infectious diseases: part 1. *Nature* 280:361–367

Ardipradja K (2001) A Study of Resistance towards the Emerging Pathogen Batrachochytrium dendrobatidis in Four Species of Australian Frogs. Honours thesis, Melbourne, Victoria, Australia: University of Melbourne

Australian Government Department of the Environment and Heritage (2004) *Draft Threat Abatement Plan for Infection of Amphibians with Chytrid Fungus Resulting in Chytridiomycosis*, Canberra, Australia: Department of the Environment and Heritage, Commonwealth of Australia. Available: http://www.jcu.edu.au/school/phtm/PHTM/frogs/chart.htm [accessed October 29, 2006]

Australian Government Department of the Environment and Heritage (2006a) *Threat Abatement Plan: Infection of Amphibians with Chytrid Fungus Resulting in Chytridiomycosis*, Canberra, Australia: Department of the Environment and Heritage, Commonwealth of Australia. Available: http://www.deh.gov.au/biodiversity/threatened/publications/tap/chytrid/pubs/chytrid-report.pdf [accessed September 19, 2006]

Australian Government Department of the Environment and Heritage (2006b) *Background Document for the Threat Abatement Plan: Infection of Amphibians with Chytrid Fungus Resulting in Chytridiomycosis*, Canberra, Australia: Department of the Environment and Heritage, Commonwealth of Australia. Available: http://www.deh.gov.au/biodiversity/threatened/publications/tap/chytrid/pubs/chytrid-background.pdf [accessed September 19, 2006]

Bell BD, Carver S, Mitchell NJ, Pledger S (2004) The recent decline of a New Zealand endemic: how and why did populations of Archey's frog *Leiopelma archeyi* crash over 1996–2001?. *Biological Conservation* 120:189–199

Berger L, Speare R, Daszak P, Green DE, Cunningham AA, Goggin CL, et al. (1998) Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. *Proceedings of the National Academy of Sciences of the United States of America* 95:9031–9036

Berger L, Speare R, Hyatt AD (1999) Chytrid fungi and amphibian declines: overview, implications and future directions. In: Campbell A (editor), Declines and Disappearances of Australian FrogsCanberra, Australia: Environment Australia, Australian

Government Department of the Environment and Heritage, pp 23–33

Berger L, et al. (2004) Effect of season and temperature on mortality in amphibians due to chytridiomycosis. *Australian Veterinary Journal* 82:31–36

Berger L, Longcore JE, Speare R, Hyatt AD, Skerratt LF (in press) Fungal diseases in amphibians. In: *Amphibian Biology Series, Vol. 8*, *Decline and Conservation of Amphibians*, Heatwole H (editor), Chipping Norton, Australia: Surrey Beatty & Sons

Bonaccorso E, Guayasamin JM, Méndez D, Speare R (2003) Chytridiomycosis in a Venezuelan amphibian (Bufonidae: *Atelopus cruciger*). *Herpetological Review* 34:331

Bosch J, Martínez-Solano I, García-París M (2001) Evidence of a chytrid fungus infection involved in the decline of the common midwife toad *(Alytes obstetricans)* in protected areas of central Spain. *Biological Conservation* 97:331–337

Broad Institute of Harvard and MIT (2006) *Batrachochytrium dendrobatidis* Sequencing Project. Available: http://www.broad.mit.edu/annotation/genome/batrachochytrium_dendrobatidis [accessed October 29, 2006]

Carey C, Bruzgul JE, Livo LJ, Walling MI, Kuehl KA, Dixon BF, et al. (2006) Experimental exposures of boreal toads *(Bufo boreas)* to a pathogenic chytrid fungus *(Batrachochytrium dendrobatidis)*.. *EcoHealth* 3:5–21

Cunningham AA, Daszak P, Hyatt A (2001) Amphibia. In: Woodford MH (editor), Quarantine and Health Screening Protocols for Wildlife Prior to Translocation and Release into the WildParis: Office International des Epizooties (OIE), Care for the Wild International, IUCN—World Conservation Union and the European Association of Zoo and Wildlife Veterinarians, pp 74–79

Daszak P, Cunningham AA, Hyatt AD (2000) Emerging infectious diseases of wildlife threats to biodiversity and human health. *Science* 287:443–449

Daszak P, Cunningham AA, Hyatt AD (2003) Infectious disease and amphibian population declines. *Diversity and Distributions* 9:141–150

Daszak P, Strieby A, Cunningham AA, Longcore JE, Brown CC, Porter D (2004) Experimental evidence that the bullfrog *(Rana catesbeiana)* is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. *Herpetological Journal* 14:201–207

Department of Environment and Conservation NSW (2005) Green and Golden Bell Frog *Litoria aurea* (Lesson 1829). Draft Recovery Plan. Unpublished report. Available: http://www.nationalparks.nsw.gov.au/PDFs/recoveryplan_green_gold_bell_frog_draft.pdf [accessed January 13, 2007]

Dohoo I, Martin W, Stryhn H (2003) *Veterinary Epidemiological Research.* Canada: AVC: Prince Edward Island

Evans AS (1976) Causation and disease. The Henle-Koch postulates revisited. *Yale Journal of Biological Medicine* 49:175–195

Eyler JM (2001) The changing assessments of John Snow's and William Farr's cholera studies. *Sozial- und Präventivmedizin* 46:225–232

Fenner F, Ratcliffe FN (1965) *Myxomatosis.* New York: Cambridge University Press

Garner TWJ, Walker S, Bosch J, Hyatt AD, Cunningham AA, Fisher MC (2005) Chytrid fungus in Europe. *Emerging Infectious Diseases* 11:1639–1641

Hanselmann R, Rodríguez A, Lampo M, Fajardo-Ramos L, Aguirre AA, Kilpatrick AM, et al. (2004) Presence of an emerging pathogen of amphibians in introduced bullfrogs *Rana catesbeiana* in Venezuela. *Biological Conservation* 120:115–119

Hudson PJ, Rizzoli A, Grenfell BT, Heesterbeck H, Dobson AP (2002) *The Ecology of Wildlife Diseases.* Oxford, UK: Oxford University Press

Johnson M, Speare R (2003) Survival of *Batrachochytrium* in water: quarantine and disease control implications. *Emerging Infectious Diseases* 9:922

La Marca E, Lips KR, Lotters S, Puschendorf R, Ibanez R, Rueda-Almonacid JV, et al. (2005) Catastrophic population declines and extinctions in neotropical harlequin frogs (Bufonidae: *Atelopus*). *Biotropica* 37:190–201

Lamirande EW, Nichols DK (2002) Effects of host age on susceptibility to cutaneous chytridiomycosis in blue-and-yellow poison dart frogs (*Dendrobates tinctorius*). In: St. Paul MN, McKinnel RG, Carlson DL (editors) Proceedings of the Sixth International Symposium on the Pathology of Reptiles and Amphibians, pp 3–13

Laurance WF, McDonald KR, Speare R (1996) Epidemic disease and the catastrophic decline of Australian rain forest frogs. *Conservation Biology* 10:406–413

Lips KR (1998) Decline of a tropical montane fauna. *Conservation Biology* 12:106–117

Lips KR (1999) Mass mortality and population declines of anurans at an upland site in western Panama. *Conservation Biology* 13:117

Lips KR, Brem F, Brenes R, Reeve JD, Alford RA, Voyles J, et al. (2006) Emerging infectious disease and the loss of biodiversity in a neotropical amphibian community. *Proceedings of the National Academy of Sciences of the United States of America* 103:3165–3170

Longcore JE, Pessier AP, Nichols DK (1999) *Batrachochytrium dendrobatidis* gen. et sp. nov. a chytrid pathogenic to amphibians. *Mycologia* 91:219–227

McCallum H (2005) Inconclusiveness of chytridiomycosis as the agent in widespread frog declines. *Conservation Biology* 19:1421–1430

McCallum H, Dobson A (1995) Detecting diseases and parasite threats to endangered species and ecosystems. *Trends in Ecology and Evolution* 10:190–194

McDonald KR, Alford RA (1999) A review of declining frogs in northern Queensland. In: Campbell A (editor), Declines and Disappearances of Australian Frogs, CanberraAustralia: Environment Australia, Australian Government Department of the Environment and Heritage, pp 14–22

McDonald KR, Méndez D, Müller R, Freeman AB, Speare R (2005) Decline in the prevalence of chytridiomycosis in frog populations in North Queensland, Australia. *Pacific Conservation Biology* 11:114–120

Mendelson JR, Lips KR, Gagliardo RW, Rabb GB, Collins JP, Diffendorfer JE, et al. (2006) Confronting amphibian declines and extinctions. *Science* 313:48

Morehouse EA, James TY, Ganley ARD, Vilgaly R, Berger L, Murphy PJ, et al. (2003) Multilocus sequence typing suggests the chytrid pathogen of amphibians is a recently emerged clone. *Molecular Ecology* 12:395–403

Morse SS (1995) Factors in the emergence of infectious diseases. *Emerging Infectious Diseases* 1:7–15

Muths E, Corn PS, Pessier AP, Green DE (2003) Evidence for disease related amphibian decline in Colorado. *Biological Conservation* 110:357–365

OIE Aquatic Animal Health Standards Commission (2003) *June Report of the Meeting of the OIE Aquatic Animal Health Standards Commission.* Paris: Office International des Epizooties

OIE Aquatic Animal Health Standards Commission (2006) *March Report of the Meeting of the OIE Aquatic Animal Health Standards Commission.* Paris: Office International des Epizooties

OIE Fish Diseases Commission (2002) *June Report of the Meeting of the OIE Fish Diseases Commission.* Paris: Office International des Epizooties

OIE Working Group on Wildlife Diseases (2001–2005) *Report of the Meeting of the OIE Working Group on Wildlife Diseases.* Paris: Office International des Epizooties

Ouellet M, Mikaelian I, Pauli BD, Rodrigues J, Green DM (2005) Historical evidence of widespread chytrid infection in North American amphibian populations. *Conservation Biology* 19:1431–1440

Pounds AJ, Bustamante MR, Coloma LA, Consuegra JA, Fogden MPL, Foster PN, et al. (2006) Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* 439:161–167

Puschendorf R (2003) *Atelopus varius* (harlequin frog) fungal infection. *Herpetological Review* 34:20

Rachowicz LJ, Hero JM, Alford RA, Taylor JW, Morgan JAT, Vredenburg VT, et al. (2005) The novel and endemic pathogen hypotheses: competing explanations for the origin of emerging infectious diseases of wildlife. *Conservation Biology* 19:1441–1448

Retallick RWR, McCallum H, Speare R (2004) Endemic infection of the amphibian chytrid fungus in a frog community post-decline. *Public Library of Science Biology* 2:e351

Scherer RD, Muths E, Noon BR, Corn PS (2005) An evaluation of weather and disease as causes of decline in two populations of boreal toads. *Ecological Applications* 15:2150–2160

Schloegel LM, Hero JM, Berger L, Speare R, McDonald K, Daszak P (2006) The decline of the sharp-snouted day frog *(Taudactylus acutirostris):* the first documented case of extinction by infection in a free-ranging wildlife species. *EcoHealth* 3:35–40

Skerratt LF, Speare R, McDonald K, Berger L, Alford RA, Mendez D, et al. (2006) Chytridiomycosis requires a global response. In: *Proceedings of the 11th International Symposium of Veterinary Epidemiology and Economics*, Cairns, Australia: ISVEE 11, 536. Available: http://www.sciquest.org.nz/default.asp?pageid=69&pub=10&vol=1 [accessed September 19, 2006]

Snow J (1890) *On the Mode of Communication of Cholera.* 2nd ed. London: John Churchill

Speare R (2006) *Amphibian Diseases Home Page.* Available: http://www.jcu.edu.au/school/phtm/PHTM/frogs/ampdis.htm [accessed October 29, 2006]

Speare R, Steering Committee of Getting the Jump on Amphibian Disease (2001) *Developing Management Strategies to Control Amphibian Diseases: Decreasing the Risks Due to Communicable Diseases*, Townsville, Australia: School of Public Health and Tropical Medicine, James Cook University. Available: http://www.jcu.edu.au/school/phtm/PHTM/frogs/chart.htm [accessed October 29, 2006]

Speare R, Skerratt LF, Berger L, Hines H, Hyatt AD, Mendez D, et al. (2005) *A Project that Designs and Trials a Pilot Survey to Map the Distribution of Chytridiomycosis (Caused by the Amphibian Chytrid Fungus) in Australian Frogs*. Final Report for Project ID 44381 (tender 63/2003) to the Australian Government Department of the Environment and Heritage, Canberra, Australia: Department of the Environment and Heritage, Commonwealth of Australia. Available: http://www.deh.gov.au/biodiversity/invasive/publications/c-disease/distribution-survey.html [accessed October 29, 2006]

Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, et al. (2004) Status and trends of amphibian declines and extinctions worldwide. *Science* 306:1783–1786

Thrushfield M (2005) *Veterinary Epidemiology.* 3rd ed. Oxford, UK: Blackwell Science

Weldon C, du Preez LH, Muller R, Hyatt AD, Speare R (2004) Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* 10:2100–2105

Wobeser GA (1994) *Investigation and Management of Disease in Wild Animals.* New York: Plenum Press

Woodhams DC, Alford RA (2005) Ecology of chytridiomycosis in rainforest stream frog assemblages of tropical Queensland. *Conservation Biology* 19:1449–1459

Woodhams DC, Alford RA, Marantelli G (2003) Emerging disease cured by elevated body temperature. *Diseases of Aquatic Organisms* 55:65–66

Wilcox BA (2006) Amphibian decline: more support for biocomplexity as a research paradigm. *EcoHealth* 3:1–2

Williams ES, Yuill T, Artois M, Fischer J, Haigh SA (2002) Emerging infectious diseases in wildlife. *Scientific and Technical Review Office International des Epizooties* 21:139–157

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 6:
Captive Issues

14-17 May 2007
Bagamoyo, Tanzania

12 February 2007

Kihansi Spray Toad

Report No. 14

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Introduction

This is the first report for the year 2007 on the captive population and health assessment of the Kihansi Spray Toad, *Nectophrynoides asperginis*.

Facility Report: WCS (Bronx Zoo)

As of 12 February 2007, the current census at WCS is comprised of a sex distribution of 43.51.185 (n = 279).

On 11 May 2006, the first of many offspring of the F_4 generation were born to C# H05037; the births continued into November. Of the unsexed individuals, 155 are from this generation. An interesting phenomenon observed with these animals is that they seem to be obtaining their adult coloration at a much smaller size than previous generations. Once mature, however, they are the same size as the other adults. Juveniles born as late as July and August are already calling and amplexing.

Over the past year, there has been a high mortality of toads from C# H05037 (F_3 generation). Necropsies have not been very revealing. Some toads reportedly died from terminal sepsis, some showed evidence of parasites, while others showed no lesions, or cause of death. Because of the rate of mortality, it was thought that perhaps the parasites were playing a larger role than initially obvious. One group, tank C, was treated with Fenbendazole for a month and seemed to yield good results with low mortality. Unfortunately it was discovered, via microscopic fecal examinations, that they still harbored parasitic infections. The toads were then medicated with an oral dose of Ivermectin. The same protocol was followed as has been successful at TOLZ. The success here was very low, with an 80% mortality of the treated animals.

Some toads have exhibited a symptom of splayed or paralyzed hind limbs with curled toes. If a specific traumatic incident (such as a fall or combat) can be associated with the splayed limbs, the toads generally recover uneventfully without treatment in about 10 minutes. If no trauma can be associated, it is thought that the cause may be related to long term exposure to phosphates in the water. With treatment, the prognosis for these toads is poor. We are currently working on various methods to effectively remove the phosphates as R/O filtration is not entirely effective.

Three toads have been found with broken front limbs. The cause of the injuries is unclear, but assumed to have been caused by combat, a fall, or other trauma to the foot. All three animals presented with the limb swollen and the toes curled on the foot of injury only. They were housed individually and treated daily with Enro. The first two recovered uneventfully and were returned to their colonies. The third is currently being treated, and appears to be making a good recovery.

Facility Report: TOLZ (Toledo Zoo)

As of 12 February 2007, the current census at TOLZ is comprised of 62.62.57= 181. They are in the process of hiring a new assistant KST keeper to help with the work load of maintaining their collection of Spray Toads.

Table 1. Spray Toad census in U.S. collections.

KIHANSI		499					
		Wild	**F1**	**F2**	**F3**	**F4**	**COMMENTS**
Bronx Zoo (WCS)	30 Nov 2000	269	0				Original group collected at Kihansi Gorge
	4 April 2001	90	203				
	3 May 2001	49	238				24 adults and 19 offspring shipped to OKCZ
	8 May 2001	48	225				
	29 August 2001	28	86				38 offspring transferred to BALT on 3 July 2001
	18 Sept. 2001	12	69				
	15 January 2002	11	67	0			
	22 July 2002	6	109	185			First F2 born 13 June 2002. The F1 figures account for 40 toads sent from NACC on 5 April 2002
	22 Nov 2002	5	74	186			47.32.186 = 265
	29 March 2003	4	59	74	1		First F3 born. 42.22.74 = 138.
	25 July 2003	4	40	55	1		25.21.53 = 99
	2 December 2003	3	9	11	1		5.19 = 24
	16 March 2004	0	*	*	1		10.21.1 = 32
	10 July 2004		6	52	1		18.23.18 = 59
	22 Sept. 2004		14	15	25		14.15.25 = 54*
	5 February 2005						8.13.10 (31)*
	16 November 2005		16	14	129		25 F3 toads sent to Toledo Zoo. 15.15.129 = 159
	2 March 2006		15	14	128		14.15.128 = 157
	12 February 2007		**5**	**6**	**113**	**155**	**43.51.185= 279***
Toledo Zoo (TOLZ)	1 February 2002	0	30				
	27 June 2002	0	15				
	6 Dec 2002	0	5				1.1.3= 5 F1 remain
	3 April 2003	0	13	5			4.9.5 = 18
	25 July 2003	0	18	14			14.11.7 = 32
	8 November 2003		15	11			14.12 = 26
	27 February 2004	0.1	9.7	3.4	0		12.12 = 24
	10 July 2004						9.6.8 = 23
	18 Sept. 2004		9	6	33		9.6.33 = 48*
	3 February 2005						13.8.44 (65)*
	2 March 2006						0.0.133*
	12 February 2007						**62.62.57= 181***

***n* = 460 in a 105.113.242 sex distribution**

*= animals mixed between generations, individual identities and generation no longer identifiable for discrete census calculations.

Male *Nectophrynoides asperginis* from colony #H05037 showing hind limb paralysis and toe curling.

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DEVELOPING NEW AMPHIBIAN QUARANTINE STANDARDS AND PRE-RELEASE SCREENING PROTOCOLS

In February 2006, the Conservation Breeding Specialist Group (CBSG) and World Association of Zoos and Aquariums (WAZA) held an Amphibian *Ex-Situ* Conservation Planning Workshop in Panama. During this workshop, recommendations where made to upgrade housing and quarantine standards currently in place at zoological institutions. These recommendations were initially criticized by many as being too impractical or extreme for AZA institutions to follow due to lack of resources and funding. However, given the global spread of chytrid fungus and the potential for new pathogens to do the same, the Amphibian Taxon Advisory Group is strongly encouraging institutions (especially those holding species designated for reintroduction) to modify their current husbandry and quarantine standards to comply with the new recommendations.

AMPHIBIAN QUARANTINE AND PREVENTIVE MEDICINE

Dr. Ryan De Voe, *Senior Veterinarian*, North Carolina Zoological Park

Two essential parts of a successful captive amphibian program are appropriate quarantine and preventative medicine protocols. Vigilance in these areas helps avoid introduction of infectious disease into an existing captive population (or to new specimens from the existing population). Currently, the standard protocols practiced by most zoos for amphibian quarantine include a 30 to 90 day observation period in a location remote from the main population, fecal screening and treatment for parasites, and a physical examination. In addition, blood collection and analysis is conducted when possible. Historically, little specific infectious disease testing has been performed on quarantined amphibians. With the emergence of chytridiomycosis and ranaviral infections as recognized amphibian pathogens, more institutions are taking measures to specifically screen for these diseases.

To screen for chytrid fungus, skin scrapings or skin biopsies can be collected and examined microscopically or processed and screened with a molecular test via polymerase chain reaction. Molecular diagnostics for chytrid fungus are available commercially through a number of laboratories. Ranavirus diagnostics are a little trickier and specific molecular tests are not routinely available, except through research laboratories. Other options for ranaviral diagnosis include viral isolation and microscopic examination of tissue samples with immunostaining. Quarantine and preventative medicine programs become even more important when dealing with captive amphibian populations involved in release programs.

A question that has plagued many program managers is how to ensure that captive produced animals do not introduce pathogens into wild populations. A novel pathogen can be devastating in a naïve population of animals, so this situation needs to be avoided at all cost. The dilemma is that we have an incomplete understanding of what microorganisms are carried by and/or are capable of causing disease in amphibians, thus there is absolutely no way anyone can guarantee an individual animal is free of infectious disease. This reality dictates that if we are going conduct reintroduction programs, we need to look at the scenario from a risk assessment standpoint. It is essential to screen for known pathogens in animals prior to release, as well as avoid contact between animals used for reintroduction and other collection animals. Furthermore, we should be vigilant about identifying new potential pathogens.

An important point to understand is that most potential pathogens, such as parasites and viruses, cause few problems in their natural host. Severe disease can occur when these organisms are transmitted to non-adapted species. A good example that many in the zoo field are familiar with is cercopithecine herpesvirus 1 (CHV1) or "Herpes B virus." In macaques CHV1 causes minimal disease, limited usually to mild ulcerative lesions of mucosal surfaces in adult animals. In non-adapted species, including humans and other non-human primates, CHV1 can cause severe or fatal encephalitis. This principle can be applied to all taxa, so great care should be taken mixing species, especially those from different regions. We know that chytridiomycosis and ranaviral infections cause few problems in some amphibian species, but have been implicated in causing local population declines or even extinctions in others. For these reasons it is appropriate to maintain captive populations of amphibians that produce offspring for release to the wild in permanent quarantine situations.

The Puerto Rican Crested Toad SSP has historically released tadpoles into ponds on Puerto Rico and allowed them to metamorph and disseminate on their own. This presents a challenge for pre-release infectious disease testing. The individual tadpoles are extremely small and any screening tests need to be rapidly completed so the larvae can be shipped to the field and release prior to metamorphosis. The advent of molecular diagnostics makes rapid turn around of tests for specific pathogens possible, though the small size of the larvae necessitates that individuals be sacrificed for testing. Currently, the Puerto Rican Crested Toad SSP is trying to develop standardized PCR testing for chytrid fungus and ranavirus that can be employed prior to sending groups of tadpoles for release. Adult animals in breeding populations should be monitored for evidence of infectious diseases including parasitism.

In summary, it is paramount that those working with captive amphibian populations be familiar with appropriate quarantine and preventative medicine protocols. Population managers directing wild release programs should continually reassess practices to ensure that all possible measures are taken to avoid introduction of pathogens into wild populations of amphibians.

A PRACTICAL LOOK AT COMPLYING WITH HIGH QUARANTINE AND HUSBANDRY STANDARDS FOR RELEASE AMPHIBIANS


© Jessi Krebs

Jessi Krebs, *Supervisor, Reptiles and Amphibians*, Omaha's Henry Doorly Zoo

The Omaha's Henry Doorly Zoo has recently developed an amphibian quarantine facility that follows preferred and minimum standards developed at the CBSG/WAZA husbandry workshop. The following information is meant to guide institutions to develop their own quarantine facilities

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using existing space, as well as give examples of how to utilize that space.

CBSG/WAZA Recommended Minimum Quarantine Standards: Location of Quarantine Facility

"Preferred standard for location of the Amphibian Quarantine Facility: Quarantine facility is a completely separate building from the cosmopolitan animal collection. Only a single species or species assemblage (an amphibian faunal group that that naturally occurs in the range country) is permitted per room. Facilities that house individual species or species assemblages in self-contained units (such as modified shipping containers) may have advantages over a dedicated building.

Minimum standard for location of Amphibian Quarantine Facility: Dedicated space in a cosmopolitan animal facility must consist of isolated rooms, containing only a single species or species assemblages as described for the preferred standard (above). Animals need to be taken care of first in the day before servicing of animals in the cosmopolitan collection. It is important for managers to understand that this constitutes the Amphibian Quarantine Facility and "shower-out" or minimum equivalent must occur prior to handling non-quarantine collection animals."

Providing dedicated quarantine space for multiple species will be the biggest challenge for institutions. Many zoos and aquariums don't have empty buildings waiting to be filled with endangered amphibians, or it may not be feasible to room off an area for one species. Take some time to look around your institution. Is there an old sea lion building for example, with the potential to house amphibians? Is there a storage room in the basement of your facility that could hold one endangered species? Just one? Modified insulated shipping cargo containers have been used in Australia and Europe for just such a purpose and an unused hallway is being modified to accommodate 20 isolation rooms at Omaha's Zoo.

Our existing space comes in the form of a 4,200 square foot passageway, with and average width of 11 feet and the entire length being 220 feet. This area was originally planed to be utilized as a public viewing area to an orangutan exhibit and a passageway to a planned panda facility. This space was never designed to house animals, so basic necessities such as environmental controls, floor drains, and a water source were not present. It was decided to build individual rooms in the existing space that would house one species or an assemblage of amphibians from the same area. As retrofitting the area with cement block walls would prove to be costly and labor intensive, it was decide to use walls constructed of two inch aluminum tubing and transparent hollow core Lexan. These materials (typically used to construct green houses) are relatively inexpensive and readily available.

Isolation rooms range in size from 8'x8'x8' to 16'x10'x8'. Though some rooms have shared walls, each unit is silicon sealed to prevent water and air seepage. This also minimizes vermin such as cockroaches from moving from room to room and transporting disease. To overcome the lack of area environmental control, each individual room utilizes a freestanding, commercially available, heating and cooling unit. This allows each room to meet the general environmental temperature needs of the designated species. A standard duct work system provides heated\cooled air to the area. Small flexible air ducts and dampers branch off of the main line to provide fresh air and maintain positive pressure for each isolation room. Filters are used on these small lines to prevent pest insects and large particles from getting into the rooms.

Since no water lines were originally run into the amphibian space, an existing cold water line running one floor above the amphibian area was tapped and run to several 300 gallon storage tanks after passing through a Reverse Osmosis unit, eliminating the chance of exposing the amphibians to outside chemical contaminants. While in the storage tanks, water is re-constituted, recirculated and filtered mechanically, as well as chemically and passed through ultra violent sterilizers. PVC plumbing lines allow the water to be pumped from the storage tanks to individual rooms where it is utilized on demand. Each tank system supplies enough water for two to five isolation rooms.

Amphibian housing in each room consists of movable rack systems. The shelving racks where purchased commercially then modified to roll and utilize a gutter system that allows all waste water to drain to one centralized sump. Recirculation systems, as well as dump and fill systems are used for the racks. Each rack utilizes three shelves with four 16 gallon, or six five gallon food storage polycarbonate boxes. These boxes house individuals or groups of amphibians. Polycarbonate containers where chosen over glass for long-term durability and ease of drilling. Individual lighting needs of each species is also integrated to these rack systems.

CBSG/WAZA Recommended Minimum Quarantine Standards: Guidelines for disposal of water and wastes:

"Facility wastewater must be treated to minimize risk of introduction of foreign pathogens out of facility and into surrounding area. Heat and pressure wastewater treatment is strongly preferred. At minimum, chlorine treatment of wastewater must take place in an amphibian-safe manner (e.g., consider chemical fumes from sterilization agents).

Solid waste disposal, including all substrate, props, gloves, etc., should be decontaminated by way of incineration, disposal by medical waste hauler or heating to a minimum of 160ºF for 20 minutes and discarded.

For carcass disposal, institutions must follow appropriate necropsy procedures. Accepted final tissue disposal options include: incineration, alkaline tissue digestion, formalin or alcohol fixation, or disposal by certified medical waste hauler."

Many people assume that all water heading down a drain will be treated by local waste-water management plants before entering water systems habituated by local amphibian populations. However, it is not uncommon for waste water management facilities to bypass standard treatment processes when faced with a surge of water from events such as spring run off or excessive rainfall, sending potential amphibian pathogens directly into local wetlands, lakes or rivers.

To prevent potential contamination of surrounding wetlands, all waste water from each isolation room is pumped out via a commercial "sump pump," through plumbing lines to centralized fifty-five gallon drums (one drum per room so there is no cross contamination of water). Once a drum is full, the waste water is disinfected, utilizing a 12 hour chlorine treatment before being released into a floor drain that was installed in the common area.

For general security issues, only specified amphibian keeper staff have access to individual rooms and the public is not allowed to visit the area. Dedicated gloves, footwear and coveralls are provided for the keepers to wear while working in the isolation rooms. Keepers also utilize dedicated footwear in the common area to minimize contamination from the other amphibian areas of the zoo. In addition, consistent, directional traffic flow is practiced during maintenance and feeding.

Food items for amphibians are obtained from commercial breeders. Upon arrival, they are taken directly to the individual isolation rooms where they are unpacked and maintained. Food items are not taken from room to room, or obtained from other areas of the Zoo.

Similar technologies and practices have been implemented by the Johannesburg Zoo of South Africa for their Amphibian Conservation Center. These methods have worked very well for them, demonstrating the transferability of the above describe techniques not only to AZA institutions but to foreign countries as well.

With approximately half of the world's amphibians threatened with extinction and with captive assurance colonies as the only immediate hope for survival for many of these species, updating quarantine standards for amphibians is a priority. This material is presented in order to demonstrate how, with a little imagination and planning, institutions can follow stricter quarantine standards without excessive cost and effort.

For further information about products and general costs please contact *jkrebs@omahazoo.com*.

SPRAY TOAD FACT SHEET

COMMON NAME: Kihansi spray toad
SCIENTIFIC NAME: *Nectophrynoides asperginis*
STATUS: USFWS- Endangered
CITES- Appendix I
IUCN- Endangered
LOCALITY: ~ 4 KM x 0.5 KM stretch of the Kihansi River Gorge, Eastern Arc mountain range in Tanzania
SUB-LOCALITY: Main falls wetland and Jabali intake
HABITAT: Grassy wetland adjacent to splash zone of falls; rocky gorge
CLIMATE: 61-78.8°F (16.1-26 ° C)
RELATIVE HUMIDITY: 60-100%

DESCRIPTION: **Adults-** Small (10-18 mm SVL, 65-660 mg), mustard-colored with dark brown lateral lines flanked by lighter stripes. Some females from Jabali ("Z" group) lack these markings. Partially webbed hind toes and lacking external tympana. Slight sexual dimorphism but often difficult to ascribe. Ventral skin whitish anteriorly to transparent in abdominal region (females seem to possess greater area of transparent skin). There appears to be seasonal integumentary adaptations for water conservation. "Z" toads overall larger in size, especially females in length and weight.

Juveniles- Tiny (5 mm SVL & 14 mg). Neonates born with dark dorsal skin and whitish ventral skin. As they grow older/larger, lateral patterns develop as metallic blue-gray streaks. Within 3-5 months' time, patterns turn brown and xanthic coloration develops.

REPRODUCTION: ***in situ*-** November –May
***ex situ*-** November-May (WCS), Annual (NACC)

GESTATION: 30 (+/-) days after conception. Ovulating females can be distinguished by looking through the semi-transparent lower abdominal skin to visualize yellow ovules. Gravid females can be distinguished by their rotund size & by visualizing dark embryonic larvae; eyes can be seen in late stages.
LITTER SIZE: 6-23 ("Z" females have larger litters)
AGE AT SEXUAL MATURITY: **~**7 months for males, ~8.5 months for females

DIET: ***in situ*-** dipterans (mostly larvae), homopterans (bugs), coleopterans (beetles), hymenopterans (ants, wasps & parasitoids), acarines (mites)and collembolans (springtails)
***Ex situ*-** Collembolans, orthopterans (pinhead-size to 10 day old crickets), dipterans (*Drosophila* fruit flies), coleopterans (*Tribolium* beetles & larvae) & mantodeans (newly hatched) mantids. WCS supplements insect prey (other than

springtails) with either a commercial calcium/vitamin powder mixed with pharmaceutical-grade $CaCO_3$ powder or Nekton-Rep.

BEHAVIOR: Terrestrial with arboreal tendencies. In captivity, several F1 toads appeared to have feigned death on multiple occasions at WCS & BALT. Toads at WCS observed to consume sloughing skin in typical anuran fashion. Toads appear to be poor swimmers and can drown fairly easily.

ENCLOSURE RECOMMENDATIONS:

Quarantine- plastic enclosures or glass tanks. Lids should be extremely tight-fitting, such as Terra-tops flexible screen tops with velcro closures. Critter-cages should have fiberglass screen in between lid and tank if toads are smaller than lid slats (or when housing gravid females). Can opt to use wet paper toweling with crumpled damp rolls inside. Cages should be kept tipped to hold a reservoir of shallow water on one end or petri dishes with small cork pieces inside. Hand mist several times daily. As soon as consistent negative fecal results are obtained, include

Breeding tank- plumbed plastic or glass aquaria with screened standpipes/overflows or strainers. Mixed, well-rinsed layer of 2 parts gravel, 1 part activated carbon, 1 part ammo-chips and 1 part crushed coral (the crushed coral is to provide some carbonate salts in standing water incase you use pure, un-reconstituted R.O. water like WCS does- this keeps our mist heads from clogging to frequently). Secure medium stones to gravel layer and add potted plants such as ferns, Chinese evergreen and creeping ficus. Cover exposed gravel with carpet moss (pre-soaked & rinsed) or live moss. Add cork bark whorls or slabs for climbing and hiding areas. Rip small pieces of Java moss and lay on top of rock, cork bark, wood and carpet moss. This will encourage live Java moss growth on everything as long as it remains moist. Add some springtails for continuous live food supply (add dead ficus or oak leaves on occasion for food).

Some form of misting system should be hooked up to the lids of tanks (i.e. Rainmaker or Pro-Mist) or ultrasonic humidifiers with tubes leading to tanks. From WCS and NACC's experience, tanks set up like false-bottom dendrobatid tanks (using an un-plumbed tank combined with a submersible pump to feed PVC rain tubes) does not appear conducive for spray toad propagation.

QUARANTINE AND VETERINARY CONSIDERATIONS:

Founders were imported with heavy nematode loads. These were originally described as lungworm species (*Rhabditiform*) from necropsies by the Cornell invertebrate pathology lab and from in-house fecal analyses. Bacterial pathogens such as *Klebsiella, Aeromonas*, *Pseudomonas* and *Klebsiella* were found from cultures. It is not known how many of these organisms may have bloomed post-mortem. The gross majority of mortality was attributed to lungworm. WCS veterinary staff believed that larval migrans may caused internal pathology as the worms caused severe internal damage.

Levamisole and ivermectin were used topically in diluted amounts, sometimes administered via Wiretrol II micropipettes (Drummond Scientific Co., Broomall, PA 19008 & available from Buhler Supply 914.423.1028 or 212.796.5895 at 1-5, 5-10 and

10-20 microLiter sizes). These drugs seemed to have slowed down some losses yet recurrences plagued the adults. Ivermectin administrations diluted to 0.03 mg/mL & dosed to each adult toad at 5 microLiters also appeared to give some toads considerable physiological stress, as toads were observed to exhibit tetany-like reactions, and a few were found dead within 3 days post-administration.

NACC veterinary staff implemented a protocol for dusting insect prey with crushed canine Panacur (fenbendazole) granules once weekly for 3 treatments. This proved to be the most successful method for NACC, and WCS followed suit and reported similar success. It is commonly believed that fenbendazole is ineffective against *Rhabdias*, yet recent work by a pathobiologist at Oklahoma State University may show that this is a type of spirurid nematode that may very well be susceptible to fenbendazole.

Although flagellate and amoebic protozoa were found in fecal analyses of captive founder and F1 toads, it does not appear to be pathogenic at this time under current management practices. BALT found evidence of strongylids when performing fecal analyses techniques on their springtail colonies & substrate. This is probably a negligible concern.

Anorexic, injured, or weak toads were placed into amphibian Ringer's solution and often given topical does of enrofloxacin at 2.27 mg/mL dilution for 5-7 days as recommended. This was usually 5-10 microLiters or 10 mcg per adult toad. Currently, one toad is being treated for trauma with a chloramphenicol bath at 20 mg/L dilution (0.2 cc chloro mixed with 1 L water) SID x 7d.

Stillbirths can be expected, and on two occasions dead embryonic toad legs were found sticking out of females' cloacae. After 2 days, if the toad was not passed, it was manually extracted gingerly. Azium (dexamethasone) was given to the female immediately after and 50% survived this procedure. This first dead toad may block the passage of subsequent living siblings.

Caesarean sections were often performed on dead gravid females. This resulted in several clutches being saved of which several progeny survived. An 18 gauge needle was the best cutting tool for this procedure.

CARE OF YOUNG: Neonates and juveniles should be removed from adult tanks as cannibalism may occur (on two occasions adults were observed attempting to consume neonates). They can be set up in deli-cups or other small containers with paper toweling or moss. Once again, moss may make it difficult for counting toadlets, yet it does not have to be changed as frequently and supports generations of springtails for the toadlets to eat.

Toadlets should be fed a diet of springtails until they grow large enough to consume pinhead crickets and fruit flies. Once this prey base is acceptable, it can be supplemented once or twice weekly. Individuals of disparate sizes should be separated over time.

LFS Cultures, (662) 236-4687 www.lfscultures.com, and The Bug Farm, www.thebugfarm.bigstep.com, are excellent sources of springtails. An alternate culture maintenance system created by Dr. Michael L. Draney of the University of Wisconsin (www.geocities.com/~fransjanssens/publicat/culture.htm, or draneym@uwgb.edu) has been adopted by OKCZ and WCS.

BREEDING RECOMMENDATIONS: At this time, no concrete population management plan is in effect. There have been over 700 F1 births and 14 F2 births from all institutions. The current census is at 77 adult, 340 F1 and 8 F2 (417) toads represented in the U.S. However, it is advisable to breed only those colonies & individuals as recommended by the PMP manager, Sam Lee. Contraception techniques such as reduced or cessation of misting, with or without slightly elevated temperatures, should be explored. There is a no-cull clause at this time as per the 1999 WCS/URT agreement.

ABBREVIATIONS USED:
WCS: Wildlife Conservation Society, Bronx Zoo
NACC: National Amphibian Conservation Center, Detroit Zoo
BALT: Baltimore Zoo
OKCZ: Oklahoma City Zoo
URT: United Republic of Tanzania
PMP: Population Management Plan

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Summary of Medical and Surgical Procedures
Kihansi Spray Toad PHVA
Wildlife Conservation Society-Bronx Zoo

Kihansi Spray Toads (*Nectophrynoides asperginis*) have been maintained at the WCS-Bronx Zoo since 2000. Collection records document the variable successes experienced in propagating this species. Medical records similarly document the medical conditions encountered while maintaining this population. The following medical problems/conditions were compiled by review of these medical records. Problems are categorized based upon the apparent primary condition or system affected; other organ systems may also be involved.

- **Death**
- **Internal Parasitism**
  - Rhabdias
  - Amoebic cysts
  - Strongyloides
  - Strongyles
  - Nematodiasis (no species)
- **Infectious (bacterial)**
  - Septicemia
- **Musculoskeletal**
  - Fracture
  - Swelling
  - Trauma
  - Paresis/tetany } **Renal?**
  - Paralysis } **Renal?**
  - Osteomalacia
  - Tremors
- **Integumentary**
  - Dermatitis
  - Abrasion
  - Subcutaneous cysts
- **Intoxication**
  - Ivermectin
- **Other Conditions**
  - Coelomic distension
  - Decreased activity/ weakness
  - Shock
  - Prolapse

These conditions are based solely upon antemortem assessment and visual and physical examination. Post-mortem examination and histopathologic investigation provide more specific final diagnoses and identification of subclinical or undetected conditions. Refer to the Pathology section of the PHVA report.

The following medical and surgical treatments were employed to ameliorate these clinical conditions.

- **Drug Treatments**
  - Anthelmintics
    - Ivermectin
    - Levamisole
    - Fenbendazole
  - Antibiotics
    - Enrofloxacin
    - Chloramphenicol
    - Amikacin
    - Piperacillin
  - Antiprotozoals
    - Metronidazole
  - Metabolics
    - Calcium gluconate
    - Vitamin B Complex
    - Amphibian Ringer's Solution
    - Dexamethasone
    - Cimetidine
- **Procedures**
  - Immobilization
  - Amputation
  - Prolapse Reduction

These treatments generally met with limited success. Challenges that were encountered include the paucity of effective drug administration routes for compromised individuals, difficulty in identifying diseased or compromised animals early in the disease process, and prohibitive restrictions on antemortem diagnostic methods (bloodwork and other laboratory procedures, diagnostic imaging, etc.) due to the diminutive size of these animals.

Internal parasitism has been a persistent problem. Deworming protocols involving feeding anthelmintic-treated crickets (either dusted or anthelmintic-fed) to the toads produced mixed results. And though it was reportedly used safely and effectively elsewhere, oral administration of dilute ivermectin was a technical challenge and seems to be associated with increased morbidity in our collection. To date, a consistently effective treatment protocol has yet to be determined. This will likely be an important consideration in any future plan to release captively produced toads.

Few anesthetic procedures have been performed with this species. MS-222 has been used recently at typically recommended dosages but this has also met with mixed results. Where experienced, morbidity may have been related to non-anesthetic factors, though the small number makes an objective determination difficult. This species may be more sensitive to the effects of this anesthetic than other amphibian species.

As of 2006, there have been no confirmed cases of iridoviral infection or Batrachochytrium (chytrid) infection. Resistance of this species to these diseases is unknown but will also undoubtedly be an important consideration in future plans for wild releases of captive individuals.

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Captive-breeding programme for the Kihansi spray toad *Nectophrynoides asperginis* at the Wildlife Conservation Society, Bronx, New York

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The Kihansi spray toad *Nectophrynoides asperginis* is a diminutive, ovoviviparous Bufonidae endemic to the Kihansi River Gorge in Tanzania. This region is part of the Udzungwa escarpment of the Eastern Arc Mountains. The species occurs within a *c.* 2 ha area, one of the smallest geographic ranges of any terrestrial vertebrate. The taxon is listed on Appendix I of CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora) and as Critically Endangered by IUCN (International Union for Conservation of Nature and Natural Resources). The Kihansi spray toad is particularly vulnerable to habitat alteration, disease and introduction of competitors or predators, any of which may cause extinction. The biology of this toad and its restricted range also make it especially susceptible to disturbance by humans. This paper discusses the efforts of the Wildlife Conservation Society (WCS) and the National Amphibian Conservation Center (NACC) to breed these toads in captivity as an integral part of the Kihansi Gorge conservation plan.

Key-words: chytridiomycosis, Kihansi spray toad, Lower Kihansi Hydroelectric Project (LKHP), National Amphibian Conservation Center (NACC), Tanzania, Wildlife Conservation Society (WCS)

The Kihansi spray toad *Nectophrynoides asperginis* was first discovered in December 1996 by Kim Howell, Peter Hawkes and David Moyer (Poynton *et al.,* 1998). The toad occurs in a *c.* 2 ha area within a wetland spray meadow along the Kihansi River Gorge in Tanzania. The taxon is listed on Appendix I of CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora) and as Critically Endangered by IUCN (2004).

Adult Kihansi spray toads are small [snout–vent length (SVL) 10–18 mm; body mass 0·45–0·66 g] and are a mustard-yellow colour with dark-brown lateral lines flanked by lighter striping. The toes of the hind-legs are partially webbed. The species has no external tympana. The ventral skin is whitish and translucent near the throat and posterior section, and the liver, fat bodies and intestines are visible. The ♀♀ have greater areas of translucent skin at the rear of the posterior abdominal region so follicular activity can be monitored and eggs and developing embryos can be seen. Females are slightly larger than ♂♂ in overall body size but it is difficult to differentiate between the sexes unless the ♀♀ are gravid, when they become large and rotund, and the cluster of developing larvae pressed up against the abdominal wall gives a bluish–green hue to the skin.

Males have a greater proportion of dark pores in the dorsal skin surface, particularly around the head and anterior dorsum. Based on observations in captivity, it would appear that only sexually active and, perhaps, dominant ♂ toads develop dark patches of interfemoral pores in the inguinal cavities (Poynton *et al.,* 1998). Females lack these interfemoral glands (Plate 1).

Neonates are born fully formed and diminutive (SVL 5 mm; body mass

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Plate 1. *Left* ♀ **and** *right* ♂ **Kihansi spray toads** *Nectophrynoides asperginis.* **The sexually active ♂ has dark, interfemoral gland patches.** *D. DeMello, Wildlife Conservation Society, New York, USA.*

0·14 g), and have dark-grey dorsal skin and white ventral skin. A lateral pattern of primarily metallic blue–grey streaks and some striations on the head start to appear as the juveniles grow. In captivity, at *c.* 6–8 weeks of age, the mustard-yellow coloration develops, the bluish streaks turn brown and sacral V-shaped lines form (Poynton *et al.,* 1998). Morphological data on preserved adult and juvenile specimens are recorded in Table 1.

DISTRIBUTION

The Eastern Arc mountain range stretches from south-east Kenya through south-central Tanzania, situated between 3 ° 20 ' and 8 ° 45 'S latitude and 35 ° 37 ' and 38 ° 48 'E longitude. This region contains the highest known biodiversity of flora and fauna of any region in Tanzania. It also contains an extremely high level of species endemism and has been identified as one of the most threatened ecosystems in the world: a true biodiversity hotspot (Mittermeier *et al.,* 1999). The Kihansi Gorge is *c.* 4 km long and 0·5 km wide and the Kihansi River flows though it and into a series of waterfalls and rapids (World Bank, 2001). The main Upper Falls at the head of the steep-sided Gorge is > 100 m high and the Lower Falls is *c.* 30 m high, although several smaller falls also exist. Along the margins of the Gorge the waterfalls create a fine spray zone that supports a wetland spray meadow along the rocky escarpments. Club moss *Selag-*

LIFE STAGE	AVERAGE MASS (g)	AVERAGE SVL (mm)	*n*
Adults	0·72	19·0	12
♂♂	0·57	16·4	6
♀♀	0·88	21·5	6
Gravid ♀♀	0·9	21·0	4
Subadults/juveniles	0·44	16·0	2
Neonates	0·02	5·3	23

Table 1. Kihansi spray toad *Nectophrynoides asperginis* **morphological data (based on measurements made on preserved specimens).**

inella kraussiana, Snail ferns *Tectaria gemmifera* and low grasses *Panicum* spp dominate the mist-shrouded rocky area (Poynton *et al.,* 1998) and the Kihansi spray toad is found in this habitat. There are three other vegetation types away from the perennial mist, Fern tree *Filicium decipiens* forest, montane forest and miombo woodland (World Bank, 2001), but the Kihansi spray toad is not found in any of these drier habitats. To date, there have been up to six sites where Kihansi spray toads have been found within the spray wetlands (S. Finlow-Bates, pers. comm.). Sympatric species include the Common squeaker *Arthroleptis stenodactylus,* Leaf litter frog *Schoutedenella xenodactyla,* Forest dwarf toad *Nectophrynoides tornieri* and Torrent frog *Arthroleptides* spp (NORPLAN, 2002a).

CONSERVATION THREATS

Lower Kihansi Hydroelectric Project (LKHP) In 1992 an environmental assessment of the area to be affected by the Tanzania Power VI project was carried out and the government of Tanzania prepared an environmental management plan. Because of the small size of the inundation region, the environmental impact was presumed to be minimal. In 1993 the project was approved and a 180 MW hydroelectric facility was constructed along the Kihansi River in south–central Tanzania. By late 1995 additional environmental-impact studies concluded that the diversion of the Kihansi River away from the Kihansi Gorge would have a significant impact on the microclimate of the habitat around the Gorge. Even so, in December 1999 the facility commenced production of power. Prior to diversion of the water for the power station, the average flow in the Kihansi River was *c.* 16 m^3/sec. In 2000, which was the first year of operation of the LKHP, a minimum bypass flow of *c.* 2 m^3/sec was maintained but this was not sufficient to generate enough spray to maintain the wetland habitat. During the dry season of that year (May–October), under this low level of bypass flow, the hydrology of the spray wetlands was altered significantly, although overflow from the LKHP dam in the wet season (March–May) caused a brief recovery in the wetland habitat. However, the vegetation composition changed from a spray meadow to more herbaceous growth (NORPLAN, 2002b). This encouraged the appearance of other species, such as forest chameleons and *N. tornieri,* which is the forest-dwelling congener of the Kihansi spray toad (A. Channing, pers. comm.). Four species of lowland-dwelling anurans, Anchieta's rocket frog *Ptychadena anchietae,* Brown spiny reed frog *Afrixalus fornasinii,* Spotted reed frog *Hyperolius puncticulatus* and Grey tree frog *Chiromantis xerampelina,* may have been introduced to the habitat accidentally by the construction team, either inside pipes or on timber (NORPLAN, 2002a). Siltation problems and the drying of the wetlands remain as potential threats to the survival of Kihansi spray toads even though conservation measures have been taken (see Conservation Measures). There were also field reports of Safari ants *Dorylus* spp invading the wetlands and becoming predators of the toads (NORPLAN, 2002c).

Intermittent high-flow release tests were carried out in the dry season of 2002 to collect data on the microclimatic conditions, the significance and stability of changes, the implications of the intermittent flow as a mitigation measure, the correlation between the Kihansi spray toad presence and microclimatic conditions, as well as the prey species and predators of the Kihansi spray toads in response to any changes (NORPLAN, 2002d). Other high-flow release experiments have been carried out at the dam, with the most recent occurring around 31 May and 1 June 2003. The bypass flow was gradually increased from 2 m^3/sec to 16 m^3/sec and the lower gates of the dam were then opened, resulting in an increase in turbidity as sediments poured out. The purpose of these high-flow release experiments was to assess the sustainability of wetland hydrology and biodiversity and to compare these data to pre-diversion estimates. The results were inconclusive but after the 2003 high-flow release experiments the Kihansi spray toad population declined precipitously.

Chytrid fungus Chytrid fungus *Batrachochytrium dendrobatidis* is an opportunistic pathogen that affects the epithelial and epidermal cells of amphibians. Several taxa are believed to have become extinct because of this disease. The spread of the fungus across the world has been from either the introduction of alien species or people carrying the fungal spores on their shoes during their travels. In 2003 Ché Weldon (a doctoral student, University of the North West, School of Environmental Sciences and Development, Potchefstroom, South Africa) and Dr James Gibbs (State University of New York, College of Environmental Science and Forestry, Syracuse, USA) surveyed the Mhalala waterfalls and Upper Spray Wetlands for evidence of the chytrid fungus. Two of the four dead Kihansi spray toads collected tested positive for chytridiomycosis, as did one Anchieta's rocket frog, a lowland species first discovered in the Gorge in 2003. In the neighbouring Udagaji Gorge only 1 km away, three of 11 Torrent frogs examined tested positive for chytrid fungus (Weldon, 2004; J. Gibbs, pers. comm.).

The Mhalala Stream and Kihansi River are two separate but adjacent systems so any deleterious effects from the experimental high-release flows conducted in June 2003 cannot explain the disappearance of Kihansi spray toads at both sites. The presence of chytridiomycosis in this moist, cool, montane environment is, however, a serious factor for concern.

POPULATION IN THE WILD

In October 1988 the estimated density of Kihansi spray toads was 4·7 toads per m^2 in the Upper Spray Wetland region in an area of 65 m × 66 m (Poynton *et al.,* 1998), which may have translated conservatively to 20 163 toads (NORPLAN, 2002a). In October 2000 the World Bank estimated that there were 11 400 toads in five wetland areas (Upper, Lower, Mhalala, Mid-Falls and Mid-Gorge Spray Wetlands), and by December 2001 *c.* 10 100 toads were thought to persist in the region (NORPLAN, 2002a).

In December 2002 the population of Kihansi spray toads was estimated as *c.* 8000 (NORPLAN, 2002a) but by early June 2003 the population was estimated to be over 17 000 individuals [Lower Kihansi Environmental Management Plan (LKEMP), pers. comm.]. It has been hypothesized that the toads took shelter in moist crevices and under the matrix of boulders but appeared later, leading to this dramatic increase in estimated population size (LKEMP, pers. comm.).

One week after the high-flow release experiments that were conducted in May/June 2003 only 43 Kihansi spray toads were observed in the area and subsequent surveys recorded less than six toads per day (J. Thompson, pers. comm.). In early August 2003 only two live and one dead Kihansi spray toads were found and no Torrent frogs were recorded at any of seven wetland sites.

On 21 January 2004 K.Z. and S.L. only observed 1.3 Kihansi spray toads at the Gorge and heard two other ♂♂ vocalizing so the population appears to have declined dramatically.

CONSERVATION MEASURES

In early 2001 the Immediate Rescue and Emergency Measures (IREM) project was established with assistance from the Norwegian Agency for Development Cooperation (NORAD) and the Swedish International Development Cooperation Agency (SIDA). This was to be a bridging project to manage immediate issues while a longer-term environmental management project for the Kihansi spray toad was developed. Studies into the effects of intermittent high water flow and the diversion of water by the dam, artificial spray systems, construction of walkways in the Kihansi Spray wetlands, ecological studies of the Kihansi spray toad, including searching for the animals, investigating the possibility of translocation of the species and the development of the Kihansi Area Conservation Plan (NORPLAN, 2002e).

Between July 2000 and March 2001 gravity-fed artificial spray systems were constructed in three areas of spray wetland affected by the diversion of the Kihansi River. These systems created a fine spray in an attempt to maintain the spray-zone microhabitat. Initially, the artificial spray systems managed to maintain the spray-zone habitat but plant-species composition still changed and within 18 months of the diversion of the water, the marsh and stream-side plants retreated and a weedy species proliferated (Quinn *et al.,* 2005).

The projected next phase of environmental management of the LKEMP included ecological monitoring, mitigation, establishing the rights of the water authority and Tanesco (owner of the hydroelectric power project) to implement hydrological resources (contractually) for the agreed purpose (i.e. electricity), and conservation of the Kihansi spray toad and the spray wetlands habitat.

Late in 2000 captive-breeding efforts were initiated by the United Republic of Tanzania and the Wildlife Conservation Society (WCS), facilitated by the U.S. Fish and Wildlife Service, CITES and TRAFFIC, to provide a safety net against extinction of the species and to gain a better understanding of the biology of the Kihansi spray toad. However, because little was known about the ecology, reproductive biology or longevity of the species, translocating fragmented sub-populations and repatriating captive-bred progeny would be a challenging undertaking. Zoological participants planned to investigate several factors, including: survivorship and recruitment as functions of varying temperature, humidity and ultraviolet-light levels; husbandry and propagation techniques; the *ex situ* reproductive life cycle, including physiological, genetic and behavioural studies; growth, skin toxicity, vocalization and communication, mating systems, genetic analyses of toad groups from disparate sites in the Gorge; parasitology and veterinary medicine; field research methods and habitat viability surveys. The aim of these investigations was to establish living cell lines, which could be used for public relations, awareness raising, education and fund-raising, and to create a Population Management Plan.

WCS led these conservation initiatives with the assistance of the National Amphibian Conservation Center (NACC) at Detroit Zoo, Michigan, and Toledo Zoo, Ohio. Maryland Zoo in Baltimore, Oklahoma City Zoological Park and Buffalo Zoological Gardens, New York, were partner institutions.

TRANSLOCATION

On 30 November 2000 499 adult Kihansi spray toads were transported to Bronx Zoo, New York. The toads were collected into plastic containers with moist towelling on the base and ventilation holes. These boxes were packed into Styrofoam-insulated boxes with ventilation holes and ice packs to keep the animals cool (*c.* 21°C). The Kihansi spray toads showed no signs of any physical trauma after transportation using this method. The majority were collected by J.S. from an area known as Upper Spray Wetlands (USW) and the Jabali Tributary in the Kihansi River Gorge, an adjacent locality further upstream. The Jabali Tributary Kihansi spray toads appeared to be more sexually dimorphic than the USW population. None of the Jabali toads died during transport and only one of the USW toads died at this time. On arrival at Bronx Zoo each toad was given a physical examination, and faecal and culture samples were collected in the late afternoon. A group of 230 toads was selected and transported to the NACC. Initially the population of Kihansi spray toads at the NACC doubled in size but then it fell off to about 32 individuals that were eventually transferred to Toledo Zoo. The discussions in this paper focus on the Kihansi spray toads maintained at WCS.

ACCOMODATION

A room was provided at WCS for the quarantine and housing of the Kihansi spray toads. A heating, ventilation and air-conditioning unit (Bohn HVAC) was used to keep the room within normal temperature and humidity ranges for the toads, based on data recorded at the collection site. In the field temperature was recorded as 16·1–26°C, with an optimal temperature in the lower twenties and humidity was 60–100%. In captivity the room was maintained within this temperature range and at 60–70% humidity.

Several strict quarantine protocols were established for working in this room, including wearing special Tyvek suits, latex gloves and utilizing sterile techniques (such as washing and disinfecting tools, and using foot baths) when handling the amphibians. These restrictions were eased after 1 year.

On 30 November 2000 the 269 adult Kihansi spray toads at WCS were separated into 13 groups of 20–31 toads. Each group was contained in a 37·9–76 litre aquarium, plumbed into central PVC drain lines. Each aquarium was fitted with a fine-mist nozzle operated by a centrally located pump with a reverse-osmosis purified water source. The misting system was activated for 6–10 minutes at a time, three to four times daily. Hand misting was also carried out two to five times per day to keep humidity levels high. The misting-system water recirculated in a closed system complete with a biological filter and ultraviolet sterilizer. The aquariums were similar to rain chambers with a false bottom, comprising a light-diffusing grate and fibreglass screening, positioned 5 cm above the floor of the aquarium. This allowed a large water volume to toad ratio and minimized nitrogenous waste contamination. Gravel, rocks, cork bark pieces, plastic cups, moss and live plants were placed on top of the false-bottom assembly. The Kihansi spray toads began calling immediately they were placed in the aquariums.

Initially full-spectrum fluorescent and ultraviolet black lights were provided. However, later 15 W halogen spots and Westron 100 mercury vapour bulbs were used.

DIET

Adult and juvenile Kihansi spray toads were fed on a diet of pinhead-size to 10 day-old crickets *Acheta domestica,* as well as fruit flies *Drosophila melanogaster* (rather than *Drosophila hydei),* aphids, hatchling mantids (Mantidae), silk-moth larvae *Bombyx mori* and small annelid and non-pathogenic nematodes, such as white worms *Enchytraeus albidus* and grindal worms *Enchytraeus* spp. Studies of gut contents of wild adult and juvenile Kihansi spray toads revealed that dipterids and their larvae rank highest in composition, with acarines (mites) and Springtails *Sinella curviseta* present (P. Hawkes, pers. comm.).

Neonates and small juveniles were fed Springtails until they are large enough to consume fruit flies, aphids and pinhead crickets. Freshly netted field plankton and porch-light plankton may also be consumed. At WCS the adults were fed two to three times per week and the toadlets three to four times per week. Nekton-Rep and a 1:1 mixture of Reptocal and pharmaceutical-grade calcium carbonate were dusted over food items at almost every meal, although supplements were not

Plate 2. A second-generation Kihansi spray toad sits on top of its F1-generation mother. *D. DeMello, Wildlife Conservation Society, New York, USA.*

dusted on Springtails because they are too small to dust without killing them. Food was offered when the misting system was not operating. Once the prey base was accepted it was dusted with the supplements once or twice a week. Toads of disparate sizes were originally separated and reintroduced once the body-size discrepancy has been eliminated to ensure that all toadlets received enough food.

REPRODUCTIVE BIOLOGY

Male toads have been observed engaging in axillary amplexus and often multiple ♂♂ would attempt to engage a single ♀. There is some speculation that the inter-femoral gland patches of ♂ Kihansi spray toads contain pheromonal components that signal to other ♂♂ during ♂–♂ amplexus. Males have often been observed on all fours stretching their rear legs out behind them to present the patches laterally, often accompanied by vocalizations, so the patches may also serve as visual signals during territorial and breeding bouts.

The founder Kihansi spray toads were calling and in amplexus on arrival at Bronx Zoo on 30 November 2000. The first captive-born toadlets, from the Jabali group, were found on 16 December. From this time onwards F1 toads were routinely transferred from the adult aquariums into smaller aquariums that were lined with wet paper towelling. Neonates had a body mass of 0·0002–0·0008 g at birth. Peak births occurred between 16 December 2000 and the end of April 2001. There was no breeding in May. Field studies corroborate this breeding season (NORPLAN, 2002a). The total number of live births for that first season in captivity was 401. (Plate 2.)

Amplexus was first observed in the WCS F1 colonies in a pair of sub-adult toads of 7 months old, even though the ♂ was one-quarter of the size of an adult ♂ and still showed juvenile patterns and coloration. An F1 ♀ of 8·5 months had visible follicles developing. Juvenile groups sharing the same parent colony were grouped together according to size and were mixed randomly in order to maintain maximum heterozygosity. At Maryland Zoo F1 ♂♂ were heard calling at 7 months of age. At WCS amplexus was observed at 9 months of age. On 19 and 28 December 2001 the first second-generation Kihansi spray toads were observed at NACC and Maryland Zoo, respectively. On 13 June 2002 the first F2 toads were observed at WCS (Fig. 1).

Although little is known about the reproductive biology of the ovoviviparous Kihansi spray toad, the embryos of this genus are known to undergo highly modified larval development in the oviduct (Thibaudeau & Altig, 1999). The forest-dwelling *N. tornieri* has two pairs of gills but other species in the genus do not. Foetal larvae undergo oral morphogenesis that implies that there are physical adaptations for feeding *in utero* (Thibaudeau & Altig, 1999). The eggs of *N. asperginis* have a 2·4 mm diameter and tadpoles are similar to those of *N. tornieri* (Poynton *et al.,* 1998). The holotype contained 16 embryos corresponding to Gosner stage 31 or Orton's stage 4. The process by which ♂♂ fertilize the oviducal eggs is still unknown. One pair of first-generation toads have been observed engaged in ventrally opposed amplexus and this behaviour has also been reported in wild Malcolm's Ethiopia toad *Altiphrynoides (Nectophrynoides) malcomi* (Grandison, 1978). Gestation in captivity appears to be 30–60 days. The largest clutch sizes recorded to date have been 24 (January 2001) from a wild-caught Jabali toad and 28 (July 2002) from an F1 toad with parents from the Jabali tributary.

Experimental manipulations of misting cycles revealed that reproductive activity can be inhibited eventually by ceasing misting or reducing it for a prolonged period. In 2003, however, it was observed that simply increasing the misting cycle did not stimulate increased reproductive behaviour (Table 2) and none of the four institutions that maintained Kihansi spray toads reported significant breeding activity for that year.

Gravid ♀♀ used to be isolated to give birth in small plastic aquariums. Live moss is the best substrate and Springtails were established in the aquariums before the toadlets were born. However, because of space and time constraints at WCS gravid ♀♀ are now left in the colonial aquariums to give birth and the toadlets have to fend for themselves in that environment. This decision was made after the discovery of 13 robust F2 toads of various sizes, which indicated that they were finding enough food and the environmental parameters were adequate for the young to grow alongside the adults. In 2000 one attempted cannibalism of a neonate by an adult Kihansi spray toad was recorded but no actual cannibalism has been observed. If ample food

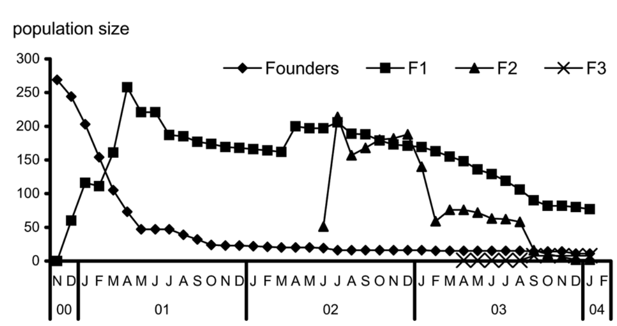

Fig. 1. Kihansi spray toad *Nectophrynoides asperginis* population trends of founders and F1, F2 and F3 generations at the Wildlife Conservation Society, Bronx, New York, from November 2000 to end January 2004.

DATE	MISTING DURATION (minutes/ day)	*n* BORN	PERIOD (days)
2002/2003			
5 Apr–24 Jun	360	24	78
25 Jun–14 Jul	210	171	20
15 Jul–13 Sep	90	122	59
14 Sep–15 Feb	24	23	153
16 Feb–18 Jun	52	23	120
19 Jun–24 Sep	300	25	91
TOTAL		388	521
MEAN		64·67	86·83
SD		65·26	46·51

Table 2. Diel misting cycle and the number of Kihansi spray toads born between April 2002 and September 2003. Increasing the misting cycle to 300 minutes per day in June to September 2003 did not increase significantly the number of offspring born.

is provided cannibalism should be a negligible factor.

HEALTH AND MORTALITY

On 4 December 2000, 4 days after their arrival at Bronx Zoo, the first founder Kihansi spray toad died and this number increased weekly (Table 3). Between January and April 2001 the highest numbers of founders died, reducing the population to only 48 in just 6 months (Fig. 1). Mortality in captive-born progeny was highest during January, May and July (Table 4). On 8 June 2001 the pathology department at WCS reported on 177 adult and 26 neonatal/juvenile deaths. Juvenile deaths were often multiple toadlets from a single aquarium born to the same parent group. The founders arrived at WCS with heavy nematode loads. Necropsies carried out at Cornell University and in-house faecal analyses originally identified these as lungworm species (Rhabditiforms). Bacterial pathogens such as *Aeromonas* spp, *Pseudomonas* spp and *Klebsiella* spp, were found from cultures, although it is not known how many of these organisms bloomed *post mortem*. Most deaths were attributed to lungworm and it was determined that larval migrans may have caused internal pathology. Four toads were screened for chytridiomycosis but they gave negative results. Histopathology was performed on 23 adults and six captive-born F1 toads. To date 56 cultures have been sent out to test for pathogenic organisms (bacterial or fungal). Whole bodies and muscle tissues were either frozen or preserved in 13:1 formalin solution or 90% ethanol solution for morphological, genetic and archival purposes. The primary disease of adult Kihansi spray toads has been lungworm infection, caused by Rhabditiform nematodes, and Gram-negative septicaemia. On several occasions gravid ♀♀ suffered from oedema and died. If oedema was diagnosed the toads were treated with a topical application of enrofloxacin (Baytril) and maintained in Amphibian Ringer's Solution (ARS). On five occasions unborn toadlets were excised from deceased ♀♀ and several caesarean-section toadlets survived.

Twice Kihansi spray toads were found in labour with the hind leg of a dead neonate partially delivered from the cloaca. It is unknown whether Kihansi spray toads are born head or leg first. On 28 March 2001 one of the ♀♀ was assisted and gave birth to three dead and five living off-

YEAR/ MONTH	FOUNDER MORTALITY	NO. FOUNDERS ALIVE AT END OF MONTH	MORTALITY RATE (%)
2000			
Nov	0	269	N/A
Dec	25	244	9
2001			
Jan	41	203	17
Feb	49	154	24
Mar	49	105	32
Apr	32	73	30
May	25	48	34

Table 3. Mortality in the founder population of Kihansi spray toads during the first 6 months in captivity at the Wildlife Conservation Society. Although a greater percentage of the original founder population died over the period, numerically most deaths occurred between January and April 2001.

spring. The ♀ was given a topical dose of dexamethasone (Azium) to treat the shock, enrofloxacin and ARS, and she survived. On 24 May 2001 the second ♀ was discovered but not assisted and she died 8 days later. All the young were dead and it is likely that the ♀ died of sepsis because the bodies of the toadlets were not expelled.

A foam pad substrate that could be used, disinfected with bleach and re-used, and then discarded, reduced the number of adult deaths. The water was no longer provided in a re-circulating, closed system, but it was flushed through each time the misting system was activated. Paper towels were used as a disposable substrate and porous furnishings were replaced with PVC pipe fittings which could be used as shelters. Levamisole (Levasole) and Ivermectin (Ivomec) were administered in small doses to each toad, and these initially proved successful in controlling lungworms in the adult colonies. However, the Kihansi spray toads were prone to relapses of the infestations and all wild-caught adults had to be treated again, this time using pulverized canine fenbendazole granules (Panacur), for a recurrence of this insidious nematode. Prey items were also dusted with Panacur once a week for 3 weeks as recommended by the veterinary staff at Detroit Zoo. It is generally thought that fenbendazole is ineffective against most *Rhabdias* spp, although the adult stage of the nematode may be more susceptible to the anthelmintic. Recent work by a pathobiologist at Oklahoma State University describes this lungworm as a new rhabditiform (A. Kocan, pers. comm.); however, treatment with fenbendazole still appears to be the most effective. Initially adult Kihansi spray toads were also moved to plumbed aquariums without substrate and plastic cages (to ease cleaning and flushing) to ensure that the nematodes were constantly flushed away during misting. However, when relapses of contamination occurred the toads were moved to planted vivaria. Neither lungworm larvae nor eggs have been found on any of the F1 toads or in the faecal samples of the F1 groups that have been examined.

In 2003 a range of health issues were recorded at the institutions maintaining the Kihansi spray toad (NACC, Toledo Zoo and Maryland Zoo), including metabolic bone disease, 'short-tongue syndrome', a condition that causes the toads to miss their prey, probably brought on

MONTH	NO. F1 BORN	NO. F1 DIED	F1 ALIVE AT END OF MONTH
2000			
Nov	0	0	0
Dec	65	5	60
2001			
Jan	104	48	116
Feb	31	36	111
Mar	63	13	161
Apr	123	26	258
May	0	37	221

Table 4. Births and deaths of F1 Kihansi spray toads during the first 6 months the founders were in captivity at WCS. The first toadlets were born on 16 December 2000 and the population increased steadily over the next 5 months.

by hypovitaminosis A, and general malaise leading to death by sepsis. A significant decline occurred in the captive population when, despite amending husbandry techniques, mature Kihansi spray toads could not be induced to breed. Inadequate staffing and limited resources brought the captive-breeding programme to a halt; however, the wild population was at near record numbers in Tanzania (*c.* 17 000; NORPLAN, 2003) and funding for the captive-breeding programme was delayed by the United Republic of Tanzania and World Bank.

All F1 Kihansi spray toads were maintained in plumbed aquariums with a mixed substrate layer of crushed coral, gravel and Ammo-Carb under live sheet moss and Java moss *Vesicularia dubyana,* on the same misting system as the adults. Moss is a good substrate for Springtails to live and breed in, ensuring a constant supply of food for the toadlets. Scoops of Springtail-laden peat moss were taken from the Springtail colonies and tucked beneath the live mosses. Plastic aquariums had a sheet of fibreglass screening fitted between the tank and lid to prevent escapes by the smaller toads and the fruit-fly prey. Juvenile mortality was high because there was not enough food for juveniles to attain optimal growth, and the availability and maintenance of the Springtail colonies are limiting factors. Toadlets were also extremely prone to desiccation.

OTHER OBSERVATIONS

Kihansi spray toads were observed consuming their sloughed skin in typical amphibian fashion. Several instances of Kihansi spray toads feigning death when they were disturbed were observed at the WCS, NACC and Maryland Zoo. When disturbed, Kihansi spray toads of all age and size classes also frequently eject water from their bladders in the typical bufonid (anuran) fashion.

COMMENTS

By June 2003 it appeared that captive-bred toads were generally more robust than their wild-caught parents, provided that proper environmental and nutritional needs were met. The husbandry of the Kihansi spray toads presented unique challenges to the zoos because of the small size of the animals and because little is known about their biology. However, improved husbandry practices were constantly evolving. As at September 2002 there were 57 founders, 315 F1- and 227 F2-generation Kihansi spray toads, representing 599 living in captivity in the

United States of America. However, by 27 February 2004 there were <70 toads in the USA at three institutions (WCS, NACC and Toledo Zoo). For every generation bred at WCS, it takes *c*. 150 days for the population to peak before declining (Fig. 1). However, this figure must be interpreted with caution because reproduction was limited (by reducing misting) at WCS in 2003 because of the high levels of staff time involved in caring for toadlets produced at such high fecundity rates and the periodic preparation for shipment of 20–30 toads to co-operating institutions.

The greatest threats facing the Kihansi spray toad are irreversible habitat alteration, because of the inadequate minimum bypass flow rates in the Gorge, and the presence of chytrid fungus. Without a viable habitat, the captive-breeding programme is futile. WCS, NACC, the consortium zoos, the World Bank and the government of Tanzania are working closely to secure the survival of this species in the wild. The greatest challenges for the zoological institutions will be to manage the colonies for optimal genetic diversity into the future. WCS is working with the AZA population management group to maintain heterozygosity.

AUTHORS' NOTE

All the Kihansi spray toads at Oklahoma Zoo ($n = 43$) had died by December 2003, and Maryland Zoo and Buffalo Zoo ($n = 15$ at each institution) sent their toads back to WCS as per the population management recommendations. As at March 2004 the population was 8.13 (♂.♀) and ten juveniles ($n = 31$) at WCS and 13.8 and 44 juveniles ($n = 65$) at Toledo Zoo. By April 2004 Detroit Zoo had shipped their last four toads (all ♀) to Toledo Zoo. As at February 2006 these numbers had grown to 15.15 and 129 juveniles ($n = 159$) at WCS and a total of 130 toads at Toledo Zoo.

In May 2004 through the mitigation plan agreed upon by the United Republic of Tanzania and the World Bank, the United Republic of Tanzania has given US$60 000 towards the continuation of the captive-breeding and husbandry programme for Kihansi spray toads at WCS and Toledo Zoo. Both organizations were able to invest in a diverse array of terraria, halogen lighting and environmental equipment to care for the toads and to stimulate reproductive activity. These efforts resulted in the population in the USA growing to >280 Kihansi spray toads by February 2006. Current contacts for the Kihansi spray toad captive-breeding and husbandry programme are William Holmstrom, Collection Manager, WCS Department of Herpetology (bholmstrom@wcs.org) and R. Andrew Odum, Curator, Department of Herpetology, Toledo Zoo (raodum@aol.com).

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PRODUCTS MENTIONED IN THE TEXT

Ammo-Carb: filtration media, manufactured by Aquarium Pharmaceuticals, Inc., Chalfont, PA 18914, USA.
Azium: dexamethasone, synthetic anti-inflammatory and glucocorticoid agent, manufactured by Schering Plough, Union, NJ 07083, USA.
Baytril: enrofloxacin, broad-spectrum antibiotic, manufactured by Bayer, Shawnee Mission, KS 66201, USA.
Bohn HVAC: a heating, ventilation and air-conditioning unit, model no. FM-0760F, manufactured by G&W Bohn A/C & R Division, Gulf and Western Mfg Co., Danville, IL 51832, USA.
Chloromycetin: chloramphenicol, broad-spectrum antibiotic, manufactured by Parke Davis, Ann Arbor, MI 48105, USA.
Ivomec: ivermectin, anthelmintic, manufactured by Merial, Iselin, NJ 08830, USA.
Levasole: levamisole, broad-spectrum anthelmintic, manufactured by Schering Plough, Union, NJ 07083, USA.
Nekton-Rep: vitamin and mineral supplement, manufactured by Nekton Produkte, D-75177 Pforzheim, Germany.
Panacur: fenbendazole, anthelmintic, manufactured by Hoechst Roussel Vet, Warren, NJ 07059, USA.
Reptocal: calcium and vitamen D_3 supplement, manufactured by Tetra GmbH, 49324 Melle, Germany.
Springtails: wingless insects, supplied by LFS Cultures (www.lfscultures.com) and The Bug Farm (www.livefoodcultures.com. A culture maintenance system created by Dr Michael L. Draney of the University of Wisconsin can be found at (www.geocities.com/fransjanssens/publicat/culture.htm, or draneym@uwgb.edu).

Tyvek suits: protective clothing, manufactured by DuPont, Wilmington, DE 19898, USA.
Westron: light bulbs, manufactured by Westron Lighting, 3590 C Oceanside Road, Oceanside, NY 11572, USA.

REFERENCES

GRANDISON, A. G. C. (1978): The occurrence of *Nectophrynoides* (Anura Bufonidae) in Ethiopia. A new concept of the genus with a description of a new species. *Monitore Zoologico Italiano N.S. suppl.* **11**(6): 119–172.

IUCN (2004): *2004 red list of threatened species.* Gland, Switzerland and Cambridge, UK: IUCN. http://www.redlist.org/

MITTERMEIER, R. A., MYERS, N., GIL, P. R. & MITTERMEIER, C. G. (1999): *Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions.* Monterrey, Mexico: CEMEX/Conservation International and Agrupación Sierra Madre.

NORPLAN (2002a): *Lower Kihansi Hydropower Project: immediate rescue and emergency measures. Final specialist report: amphibian studies.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

NORPLAN (2002b): *Lower Kihansi Hydropower Project: immediate rescue and emergency measures. Final specialist report: vegetation studies.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

NORPLAN (2002c): *Lower Kihansi Hydropower Project: immediate rescue and emergency measures. Final specialist report: entomological studies.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

NORPLAN (2002d): *Lower Kihansi Hydropower Project: Lower Kihansi Environmental Management Project (LKEMP). Attachment 5. Preliminary report: on the first set of dry season flow manipulation tests, September 2002.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

NORPLAN (2002e): *Lower Kihansi Hydropower Project: immediate rescue and emergency measures. Final main report: executive summary.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

NORPLAN (2003): *Lower Kihansi Hydropower Project: draft final report.* Report produced for Tanzania Electric Supply Company Ltd (TANESCO), Dar es Salaam, Tanzania.

POYNTON, J. C., HOWELL, K. M., CLARKE, B. T. & LOVETT. J. C. (1998): A critically endangered new species of *Nectophrynoides* (Anura: Bufonidae) from the Kihansi Gorge, Udzungwa Mountains, Tanzania. *African Journal of Herpetology* **47:** 59–67.

QUINN, C. H., NDANGALASI, H. J., GERSTLE, J. & LOVETT, J. C. (2005): Effect of the Lower Kihansi Hydropower Project and post-project mitigation measures on wetland vegetation in Kihansi Gorge, Tanzania. *Biodiversity and Conservation* **14:** 297–308.

THIBAUDEAU, G. & ALTIG, R. (1999): Endotrophic anurans: development and evolution. In *Tadpoles: the biology of anuran larvae:* 170–188. McDiarmid, R. W. & Altig, R. (Eds). Chicago, IL: Chicago University Press.

WELDON, C. (2004). Preliminary report: Chytridiomycosis risk assessment in the Kihansi and Udagaji Gorges, Eastern Arch Mts., Tanzania. *Lower Kihansi Hydropower Project Report* **January.**

WORLD BANK (2001): Environment and social development unit, Africa regional office. Tanzania. *Lower Kihansi Environmental Management Technical Assistance Project Report No. T7444-TA* **May 29.**

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Wildlife Conservation Society Kihansi Spray Toad (*Nectophrynoides asperginis*) Mortality Summary Information
Population Health Viability Assessment Workshop
Bagamoyo, Tanzania May 2007

D. McAloose

Kihansi Spray toads (*Nectophrynoides asperginis*) were introduced into the animal collections of the Wildlife Conservation Society (WCS) in 2000. The first mortalities and post-mortem examinations occurred late in that year. Post-mortem investigations provide a holistic view of the clinically significant and pathologic processes that existed in an animal at the time of its death and are important in understanding the cause and establishing the relative significance of disease processes in order to maintain healthy populations of animals. Pathology reports include (at a minimum) clinically relevant historical information, descriptions of the gross post-mortem and histologic (microscopic) examinations, results of ancillary diagnostic procedures (e.g. microbiology, virology, polymerase chain reaction (PCR), special stains on tissue sections for bacteria, fungus) and interpretive comments related to clinical illness and identified abnormalities. Certain circumstances, such as advanced post-mortem autolysis or extensive predation or post-mortem scavenging, may make a carcass or parts of a carcass unsuitable or unavailable for review. In these cases, caution must be exercised in interpreting pathologic findings in examined tissues as they may reflect an incomplete picture of the factors leading to death.

The following is summary information gathered from census information and Pathology Reports for all KSTs submitted for post-mortem examination from the time of the arrival of the first animals into the collection in 2000 through March 2007. Summary information below reflects data collected from complete Kihansi Spray toad Pathology Reports in which all of the above criteria were met.

	Total
Animal Submissions (12/2000- 3/2007)	378
Male	4
Female	126
Sex not determined	145
Sex not documented	59
Natural death	163
Elective euthanasia	3
Death type not documented	212

WCS Kihansi Spray Toad Mortality Summary

Year	Population Count (maximum for calendar year)	Total Necropsy Submissions	Complete Pathology Report
2000		15	9
2001	362	266	95
2002	331	11	11
2003	268	25	24
2004	60	12	12
2005	159	4	4
2006	313	41	41
2007 (to date)	320	4	3

General Diagnosis Categories	**Total**
Nematodiasis	101
Nematodiasis with inflammation	54
Other infection (non-nematode infection) with inflammation	15
Other infection (non-nematode infection) without inflammation	45
Inflammation (no determined cause)	57
Sepsis	22
Other (no nematode, other infectious, inflammation, sepsis diagnoses)	87

Nematodiasis

The most consistently significant factor in toad morbidity and mortality at the WCS has been parasitism due to nematodes (round worms). Nematodiasis was initially identified as the cause of verminous pneumonia in 2000 and as the cause of verminous enteritis in 2005. Overall, nematodes were identified in approximately half of all reviewed, completed Pathology Reports (101/199; 51%). When present in the lung, nematodes were generally associated with an inflammatory response (45/66; 68%) and both adult and larval parasites were seen. Parasites recovered from affected tissues were identified as *Rhabdias* sp. in nematode infections from 2000 through 2001. Parasites were not present in KST post-mortem specimens examined in 2003 or 2004 but were identified again as a significant cause of disease in 2005. Unlike earlier cases, all of the parasites in cases from 2005 to present were associated with larval parasites (no adults have been found) and the primarily affected tissue was the intestinal tract rather than the lung. Parasite eggs in fecal samples from a few of the affected animals had morphology consistent with either *Strongyloides* sp. or *Rhabdias* sp. (morphologic examination cannot differentiate the eggs of these two parasites and to date no adults or larva have been present in examined fecal samples). It is interesting to note the presence of parasites has not always been associated with inflammation. In these situations, the presence of the parasites has been considered an incidental finding.

WCS Kihansi Spray Toad Mortality Summary

Nematode	Any Tissue	Lung	Verminous Pneumonia	Intestine	Verminous Enteritis
Total	101	66	45	65	8
2000	8	6	3	5	1
2001	71	58	42	40	4
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	1	0	0	1	0
2006	19	2	0	17	2
2007	2	0	0	2	1

Other Infectious Disease Diagnoses

Infections due to fungus (non-chytrid), bacteria, protozoa, amoeba, or trematodes rather than to nematodes have been identified sporadically (60/199; 30%) in KSTs maintained at the WCS. In a small number of these cases (15/199; 8%), infection, whether primary or opportunistic, was associated with an inflammatory response and likely contributed to morbidity and mortality. Inflammatory infections occurred in the skin, heart, intestine, eye, skeletal muscle and pharynx. Of these cases, concurrent nematodiasis and associated inflammation was present in approximately one quarter of the cases (4/15; 27%). In general; however, non-nematode infections were not associated with inflammation (45/199; 23%). In these cases, the presence of the infectious agent was considered an incidental finding or was consistent with post-mortem colonization. Such cases included intralumenal gastric and/or intestinal fungus (non-chytrid), protozoa or amoeba, fungal infections of the skin or skeletal muscle, liver or adipose tissue trematodiasis, subcutaneous, ocular or disseminated protozoa, or disseminated amoeba. Intravascular ciliated protozoa, which have been seen in some collections of KSTs, have not been identified in KSTs maintained at the WCS.

Other infectious disease diagnosis	Inflammation	Nematode infection without inflammation	Nematode infection with inflammation	Total
X				45
X	X			15
X	X	X		6
X	X		X	4

Inflammation (no identified cause)

Inflammation is the basic way in which the body responds to any of a number of insults (e.g. infection, trauma) with the key features being redness, swelling, pain and the generation of heat. It can develop as the direct effect of local tissue damage or can reflect a non-specific systemic response. Inflammation, in one or multiple sites and in the absence of an identified cause, was present in 57 animals (57/199; 29%) and 98 tissues. The most common sites in which inflammation (no identified cause) was diagnosed were the kidney (27), liver (15), skin (15) and intestinal tract (13). Other sites included connective tissue, eye, coelom, heart, esophagus, tongue, pharynx, skeletal muscle, lung, ovary, nasal cavity, spleen and adipose tissue.

Other Diagnoses

Diagnoses not due to infections, inflammation or sepsis occurred with variable frequency and severity with no consistent mortality or temporal patterns. Some of the diagnoses were not associated with morbidity or mortality, but rather documented normal events (e.g. gravid). In most instances, the significance of the identified process relative to the animal's death was unclear. Most common among "other" diagnoses were: gravid (29), hepatic lipidosis (21), renal tubular mineralization (19), renal (18) or hepatic (15) extramedullary hematopoiesis, thin body condition (15), and posterior paresis (9). Other diagnoses included anisokaryosis and amphophilia (intestinal epithelium), cytoplasmic swelling/clearing, liver degeneration, dystocia, pleural edema, epidermal hyperplasia, liver fibrosis, liver glycogen accumulation, melanomacrophage hyperplasia, biliary hyperplasia, renal tubular epithelial cytoplasmic globules, epicardial mineralization, posterior paresis, squamous metaplasia (tongue), stillborn, renal tubular ectasia, renal tubular dilation, renal tubular degeneration/necrosis and trauma. Posterior paresis was noted clinically in 9 animals (9/199; 5%) from 2003-2006. Underlying histologic lesions to explain the clinical disease were not found in any case.

Addendum (4/23/2007)
Chytridiomycosis

Chytridiomycosis due to *Batrachochytrium dendrobatidis* was first identified during a mortality event in KSTs that began on April 9, 2007. During this event, all of the animals (49 KSTs) in a single tank died over the course two weeks. Diagnosis was made through histologic examination and subsequent confirmation with polymerase chain reaction (PCR) testing. Ongoing investigations (including PCR) into the source and time of introduction of chytrid infection into the collection are ongoing. Historically, histologic examination of necropsy cases through the years (and re-examination of archived case materials in response to the recent outbreak) have been negative for the organism. PCR testing for chytrid was performed on five of 15 animals submitted for post-mortem examination in 2000; results in all five cases were negative.

BEST PRACTICES WORKING GROUP
Quarantine Subgroup

Group members:
Allan Pessier, Dante Fenolio, Karen Graham

Preamble

Extended discussion in the entire Best Practices Working Group involved standards for quarantine and long-term disease risk management, especially in regard to captive animals destined for reintroduction into the wild. Chytridiomycosis is an example of a devastating infectious disease involved in amphibian population declines thought to have been disseminated worldwide by international animal movements. The outlined quarantine standards, although rigorous, seek to minimize the risk of introducing additional disease threats to imperiled amphibian populations. The risk of introduction of important infectious diseases to novel locations increases when animals from a variety of distinct geographic regions are housed in very close proximity such as in the cosmopolitan animal collections typical of most zoological institutions. The group had concerns that incorporating stringent criteria may prohibit important zoological institutions from participating in ex-situ conservation efforts involving releases to the wild; however, it was felt that high quarantine standards must be established to decrease the spread of amphibian pathogens. While we acknowledge that flexibility in guidelines will be necessary, certain standards are essential. In all circumstances "preferred standard" is the safest and recommended scenario. If the preferred standard is not used, participating institutions must adhere to the strictest of standards for the options we have provided.

We define "amphibian quarantine facility" (AQF) as a permanent quarantine facility eliminating exposure of range country animals to cosmopolitan zoo collections of animals from broad geographic origins. Animal destined for release to the wild never leave the AQF, except for return to the range country.

Carbon filters are being applied in two of our procedures to reduce the risk of exposure of valuable and sensitive amphibians to possible chemical contaminants (e.g. pesticides, water treatment chemicals, and heavy metals).

Quarantine 1: Standards for out-of-range permanent quarantine facilities with intent to return to the wild in range country

The primary concern for this level of quarantine is preventing acquisition of an infectious disease by animals destined to be released into the wild. Additional concerns include transmission of disease between distinct species or species assemblanges within the AQF and disease transmission from species in the AQF to collection animals or native amphibians.

Preferred standard for location of the AQF: Quarantine facility is a completely separate building from the cosmopolitan animal collection. Only a single species or species assemblage (an amphibian faunal group that that naturally occurs in the range country) is permitted per room. Facilities that house individual species or species assemblanges in self-contained units (such as modified shipping containers) may have advantages over a dedicated building.

Minimum standard for location of AQF: Dedicated space in a cosmopolitan animal facility must consist of isolated rooms, containing only a single species or species assemblages as described for the preferred standard (above). Animals need to be taken care of ***first*** in the day before servicing of animals in the cosmopolitan collection. It is important for managers to understand that this constitutes the AQF and “shower-out” or minimum equivalent must occur ***prior*** to handling non-quarantine collection animals (see standards for working between species and species assemblages below).

Preferred standard for working between species and species assemblanges: Dedicated clothing and footwear should be available for each species and changed before working with a different species or species assemblage. Disposable protective clothing (e.g. Tyvek suits) may be useful in this regard. Ideally, keepers would have appropriate facilities to shower between servicing each species or species assemblage housed in the AQF (“shower out”). Gloves must be worn while accessing amphibian enclosures. Depending on pathogen risk, dedicated glove use may be required per individual container, per species, or per faunal group.

Minimum standard for working between species and species assemblanges: Dedicated clothing and footwear should be available for each species and changed before working with a different species or species assemblage. Disposable protective clothing (e.g. Tyvek suits) may be useful in this regard. Gloves must be worn while accessing amphibian enclosures. Depending on pathogen risk, dedicated glove use may be required per individual container, per species, or per faunal group.

Guidelines for disposal of water and wastes: Facility wastewater must be treated to minimize risk of introduction of foreign pathogens out of facility and into surrounding area. Heat and pressure wastewater treatment is strongly preferred. At minimum, chlorine treatment of wastewater must take place in an amphibian-safe manner (e.g., consider chemical fumes from sterilization agents).

Solid waste disposal, including all substrate, props, gloves, etc., should be decontaminated by way of incineration, disposal by medical waste hauler or heating to a minimum of 160ºF for 20 minutes and discarded.

For carcass disposal, institutions must follow appropriate necropsy procedures. Accepted final tissue disposal options include: incineration, alkaline tissue digestion, formalin or alcohol fixation, or disposal by certified medical waste hauler; thus, complete uniform change, inclusive of footwear, is necessary.

Room security is high priority: Entrance or access to rooms in the AQF by native wildlife, vermin, or in shared-facility scenarios, escaped collection amphibians, can result in pathogen transfer.

Cockroaches and other vermin are known to infiltrate amphibian enclosures and can be a source of disease transport. Take into consideration their movement through plumbing, preference for damp environments, and ease of movement through narrow spaces (particularly in the juvenile stage). Ventilation systems need to be outfitted with filters to stem the influx of pest insects that could become cage to cage pathogen carriers.

Preferred standard for room security: Rooms are vermin-proof especially for cockroaches.

Quarantine 2: Standards for in-range country facilities with intent to return to the wild

The primary concerns with these facilities include the entrance of a pathogen but not necessarily the exit (i.e., where significant pathogens may already exist). However, under some circumstances, such as incorporating related species from isolated geographic ranges within the range country (e.g., two river valleys separated by a high altitude ridge), stricter criteria may be necessary. These decisions should be deferred to regional experts in country.

Colonies should not come into contact with any other captive-maintained amphibians (cosmopolitan animal facilities as described above). In the event that it is necessary to incorporate animals into in-country institutions that maintain other animals, the **Quarantine 1** level of standards must be applied

Animals brought into these facilities should be treated for known disease problems of concern (such as chytridiomycosis). It may not be necessary to cover all possible pathogens such as some intestinal parasites or commensal fauna/flora.

Where known disease conditions exist in the wild, water entering the facility must be obtained from a disease free source ***OR*** treated to safeguard inhabitants. Heat pressure treatment is the preferred standard. Options include sediment prefilters capable of eliminating small-sized pathogens or chemical disinfection (e.g. chlorine bleach) There are serious concerns about accidental and catastrophic exposure of resident amphibians to chemicals as well as environmental implications of chemical treatment.

To prevent reinfection with pathogens of concern, it is important that native amphibians cannot get into the facility and preferable that the facility be as secure as possible.

Field clothing should not be worn in the amphibian facility and dedicated clothing is the preferred standard.

Quarantine 3: *Ex situ* out-of-range for display, research, education, with no possibility of return to the wild in range country

Animals are processed through normal health screening procedures. Treatment for known disease risks (e.g., chytridiomycosis) apply. For disposal requirements for bedding, carcasses, etc., standards set above for highest quarantine level apply.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 7:
Reintroductions

14-17 May 2007
Bagamoyo, Tanzania

WILDLIFE CONSERVATION SOCIETY

TOLEDO ZOO

IUCN Technical Guidelines on the Management of *Ex-situ* populations for Conservation

Approved at the 14th Meeting of the Programme Committee of Council, Gland Switzerland, 10 December 2002

PREAMBLE

IUCN affirms that a goal of conservation is the maintenance of existing genetic diversity and viable populations of all taxa in the wild in order to maintain biological interactions, ecological processes and function. Conservation managers and decision-makers should adopt a realistic and integrated approach to conservation implementation. The threats to biodiversity in situ continue to expand, and taxa have to survive in increasingly human-modified environments. Threats, which include habitat loss, climate change, unsustainable use, and invasive and pathogenic organisms, can be difficult to control. The reality of the current situation is that it will not be possible to ensure the survival of an increasing number of threatened taxa without effectively using a diverse range of complementary conservation approaches and techniques including, for some taxa, increasing the role and practical use of ex situ techniques.

If the decision to bring a taxon under ex situ management is left until extinction is imminent, it is frequently too late to effectively implement, thus risking permanent loss of the taxon. Moreover, ex situ conservation should be considered as a tool to ensure the survival of the wild population. Ex situ management should be considered only as an alternative to the imperative of in situ management in exceptional circumstances, and effective integration between in situ and ex situ approaches should be sought wherever possible.

The decision to implement an ex situ conservation programme as part of a formalised conservation management or recovery plan and the specific design of and prescription for such an ex situ programme will depend on the taxon's circumstances and conservation needs. A taxon-specific conservation plan may involve a range of ex situ objectives, including short-, medium- and long-term maintenance of ex situ stocks. This can utilise a variety of techniques including reproduction propagation, germplasm banking, applied research, reinforcement of existing populations and re-introduction into the wild or controlled environments. The objectives and overall purpose should be clearly stated and agreed among organisations participating in the programme, and other relevant stakeholders including landowners and users of the taxon involved. In order to maximise their full potential in conservation, ex situ facilities and their co-operative networks should adopt the guidelines defined by the Convention on Biological Diversity (CBD), the International Agenda for Botanic Gardens in Conservation, Center for Plant Conservation and the World Zoo Conservation Strategy, along with other guidelines, strategies, and relevant legislative requirements at national and regional levels. IUCN recognizes the considerable set of resources committed worldwide to ex situ conservation by the world's zoological and botanical gardens, gene banks and other ex situ facilities. The effective utilisation of these resources represents an essential component of conservation strategies at all levels.

VISION

To maintain present biodiversity levels through all available and effective means including, where appropriate, ex situ propagation, translocation and other ex situ methodologies.

GOAL

Those responsible for managing ex situ plant and animal populations and facilities will use all resources and means at their disposal to maximise the conservation and utilitarian values of these populations, including:

1) increasing public and political awareness and understanding of important conservation issues and the significance of extinction;
2) co-ordinated genetic and demographic population management of threatened taxa;
3) re-introduction and support to wild populations;
4) habitat restoration and management;
5) long-term gene and biomaterial banking;
6) institutional strengthening and professional capacity building;
7) appropriate benefit sharing;
8) research on biological and ecological questions relevant to in situ conservation; and
9) fundraising to support all of the above.

Ex situ agencies and institutions must follow national and international obligations with regard to access and benefit sharing (as outlined in the CBD) and other legally binding instruments such as CITES, to ensure full collaboration with all range States. Priority should be given to the ex situ management of threatened taxa (according to the latest IUCN Red List Categories) and threatened populations of economic or social/cultural importance. Ex situ programmes are often best situated close to or within the ecogeographic range of the target taxa and where possible within the range State. Nevertheless a role for international and extra regional support for ex situ conservation is also recognised. The option of locating the ex situ programme outside the taxa's natural range should be considered if the taxa is threatened by natural catastrophes, political and social disruptions, or if further germplasm banking, propagation, research, isolation or reintroduction facilities are required and cannot be feasibly established. In all cases, ex situ populations should be managed in ways that minimize the loss of capacity for expression of natural behaviours and loss of ability to later again thrive in natural habitats.

TECHNICAL GUIDELINES

The basis for responsible ex situ population management in support of conservation is founded on benefits for both threatened taxa and associated habitats.

- The primary objective of maintaining ex situ populations is to help support the conservation of a threatened taxon, its genetic diversity, and its habitat. Ex situ programmes should give added value to other complementary programmes for conservation.

Although there will be taxa-specific exceptions due to unique life histories, the decision to initiate ex situ programmes should be based on one or more of the appropriate IUCN Red List Criteria, including:

1. When the taxa/population is prone to effects of human activities or stochastic events or

2. When the taxa/population is likely to become Critically Endangered, Extinct in the Wild, or Extinct in a very short time. Additional criteria may need to be considered in some cases where taxa or populations of cultural importance, and significant economic or scientific importance, are threatened. All Critically Endangered and Extinct in the Wild taxa should be subject to ex situ management to ensure recovery of wild populations.

- Ex situ conservation should be initiated only when an understanding of the target taxon's biology and ex situ management and storage needs are at a level where there is a reasonable probability that successful enhancement of species conservation can be achieved; or where the development of such protocols could be achieved within the time frame of the taxon's required conservation management, ideally before the taxa becomes threatened in the wild. Ex situ institutions are strongly urged to develop ex situ protocols prior to any forthcoming ex situ management. Consideration must be given to institutional viability before embarking on a long term ex situ project.
- For those threatened taxa for which husbandry and/or cultivation protocols do not exist, surrogates of closely related taxa can serve important functions, for example in research and the development of protocols, conservation biology research, staff training, public education and fundraising.
- While some ex situ populations may have been established prior to the ratification of the CBD, all ex situ and in situ populations should be managed in an integrated, multidisciplinary manner, and where possible, in accordance with the principles and provisions of the CBD.
- Extreme and desperate situations, where taxa/populations are in imminent risk of extinction, must be dealt with on an emergency basis. This action must be implemented with the full consent and support of the range State.
- All ex situ populations must be managed so as to reduce risk of loss through natural catastrophe, disease or political upheaval. Safeguards include effective quarantine procedures, disease and pathogen monitoring, and duplication of stored germplasm samples in different locations and provision of emergency power supplies to support collection needs (e.g. climate control for long term germplasm repositories).
- All ex situ populations should be managed so as to reduce the risk of invasive escape from propagation, display and research facilities. Taxa should be assessed as to their invasive potential and appropriate controls taken to avoid escape and subsequent naturalisation.
- The management of ex situ populations must minimise any deleterious effects of ex situ management, such as loss of genetic diversity, artificial selection, pathogen transfer and hybridisation, in the interest of maintaining the genetic integrity and viability of such material. Particular attention should be paid to initial sampling techniques, which should be designed to capture as much wild genetic variability as practicable. Ex situ practitioners should adhere to, and further develop,

any taxon- or region-specific record keeping and genetic management guidelines produced by ex situ management agencies.

- Those responsible for managing ex situ populations and facilities should seek both to increase public awareness, concern and support for biodiversity, and to support the implementation of conservation management, through education, fundraising and professional capacity building programmes, and by supporting direct action in situ.
- Where appropriate, data and the results of research derived from ex situ collections and ex situ methodologies should be made freely available to ongoing in-country management programmes concerned with supporting conservation of in situ populations, their habitats, and the ecosystems and landscapes in which they occur .

NB. Ex situ conservation is defined here, as in the CBD, as "the conservation of components of biological diversity outside their natural habitats". Ex situ collections include whole plant or animal collections, zoological parks and botanic gardens, wildlife research facilities, and germplasm collections of wild and domesticated taxa (zygotes, gametes and somatic tissue).

Translocation of living organisms

IUCN POSITION STATEMENT

4 September 1987

THE IUCN POSITION STATEMENT ON TRANSLOCATION OF LIVING ORGANISMS

INTRODUCTIONS, RE-INTRODUCTIONS AND RE-STOCKING

Prepared by the Species Survival Commission in collaboration with the Commission on Ecology, and the Commission on Environmental Policy, Law and Administration

As approved by the 22nd Meeting of the IUCN Council, Gland, Switzerland

4 September 1987

IUCN Position Statement on Translocation of Living Organisms:

INTRODUCTIONS, REINTRODUCTIONS AND RE-STOCKING

Prepared by the Species Survival Commission in collaboration with the Commission on Ecology, and the Commission on Environmental Policy, Law and Administration
Approved by the 22nd Meeting of the IUCN Council, Gland, Switzerland, 4th September 1987

FOREWORD

This statement sets out IUCN's position on translocation of living organisms, covering introductions, re-introductions and re-stocking. The implications of these three sorts of translocation are very different so the paper is divided into four parts dealing with Introductions, Re-introductions, Re-stocking and Administrative Implications, respectively.

DEFINITIONS:

Translocation is the movement of living organisms from one area with free release in another. The three main classes of translocation distinguished in this document are defined as follows:

- **Introduction** of an organism is the intentional or accidental dispersal by human agency of a living organism outside its historically known native range.
- **Re-introduction** of an organism is the intentional movement of an organism into a part of its native range from which it has disappeared or become extirpated in historic times as a result of human activities or natural catastrophe.
- **Re-stocking** is the movement of numbers of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat.

Translocations are powerful tools for the management of the natural and man made environment which, properly used, can bring great benefits to natural biological systems and to man, but like other powerful tools they have the potential to cause enormous damage if misused. This IUCN statement describes the advantageous uses of translocations and the work and precautions needed to avoid the disastrous consequences of poorly planned translocations.

PART I

INTRODUCTIONS

BACKGROUND

Non-native (exotic) species have been introduced into areas where they did not formerly exist for a variety of reasons, such as economic development, improvement of hunting and fishing, ornamentation, or maintenance of the cultures of migrated human communities. The damage done by harmful introductions to natural systems far outweighs the benefit derived from them. The introduction and establishment of alien species in areas where they did not formerly occur, as an accidental or intended result of human activities, has often been directly harmful to the native plants and animals of many parts of the world and to the welfare of mankind.

The establishment of introduced alien species has broken down the genetic isolation of communities of co-evolving species of plants and animals. Such isolation has been essential for the evolution and maintenance of the diversity of plants and animals composing the biological wealth of our planet. Disturbance of this isolation by alien species has interfered with the dynamics of natural systems causing the premature extinction of species. Especially successful and aggressive invasive species of plants and animals increasingly dominate large areas having replaced diverse autochthonous communities. Islands, in the broad sense, including isolated biological systems such as lakes or isolated mountains, are especially vulnerable to introductions because their often simple ecosystems offer refuge for species that are not aggressive competitors. As a result of their isolation they are of special value because of high endemism (relatively large numbers of unique local forms) evolved under the particular conditions of these islands over a long period of time. These endemic species are often rare and highly specialised in their ecological requirements and may be remnants of extensive communities from bygone ages, as exemplified by the Pleistocene refugia of Africa and Amazonia.

The diversity of plants and animals in the natural world is becoming increasingly important to man as their demands on the natural world increase in both quantity and variety, notwithstanding their dependence on crops and domestic animals nurtured within an increasingly uniform artificial and consequently vulnerable agricultural environment.

Introductions, can be beneficial to man. Nevertheless the following sections define areas in which the introduction of alien organisms is not conducive to good management, and describe the sorts of decisions that should be made before introduction of an alien species is made.

To reduce the damaging impact of introductions on the balance of natural systems, governments should provide the legal authority and administrative support that will promote implementation of the following approach.

Intentional Introduction

General

1. Introduction of an alien species should only be considered if clear and well defined benefits to man or natural communities can be foreseen.
2. Introduction of an alien species should only be considered if no native species is considered suitable for the purpose for which the introduction is being made.

Introductions to Natural Habitats

3. No alien species should be deliberately introduced into any natural habitat, island, lake, sea, ocean or centre of endemism, whether within or beyond the limits of national jurisdiction. A natural habitat is defined as a habitat not perceptibly altered by man. Where it would be effective, such areas should be surrounded by a buffer zone sufficiently large to prevent unaided spread of alien species from nearby areas. No alien introduction should be made within the buffer zone if it is likely to spread into neighbouring natural areas.

Introduction into Semi-natural Habitat

4. No alien species should be introduced into a semi-natural habitat unless there are exceptional reasons for doing so , and only when the operation has been comprehensively investigated and carefully planned in advance. A semi-natural habitat is one which has been detectably changed by man's actions or one which is managed by man, but still resembles a natural habitat in the diversity of its species and the complexity of their interrelationships. This excludes arable farm land, planted ley pasture and timber plantations.

Introductions into Man-made Habitat

5. An assessment should be made of the effects on surrounding natural and semi-natural habitats of the introduction of any species, sub-species, or variety of plant to artificial, arable, ley pasture or other predominantly monocultural forest systems. Appropriate action should be taken to minimise negative effects.

Planning a Beneficial introduction

6. Essential features of investigation and planning consist of:
    - an assessment phase culminating in a decision on the desirability of the introduction;
    - an experimental, controlled trial;
    - the extensive introduction phase with monitoring and follow-up.

THE ASSESSMENT PHASE

Investigation and planning should take the following factors into account:

a) No species should be considered for introduction to a new habitat until the factors which limit its distribution and abundance in its native range have been thoroughly studied and understood by competent ecologists and its probable dispersal pattern appraised.

Special attention should be paid to the following questions:

- What is the probability of the exotic species increasing in numbers so that it causes damage to the environment, especially to the biotic community into which it will be introduced?
- What is the probability that the exotic species will spread and invade habitats besides those into which the introduction is planned? Special attention should be paid to the exotic species' mode of dispersal.
- How will the introduction of the exotic proceed during all phases of the biological and climatic cycles of the area where the introduction is planned? It has been found that fire, drought and flood can greatly alter the rate of propagation and spread of plants.
- What is the capacity of the species to eradicate or reduce native species by interbreeding with them?
- Will an exotic plant interbreed with a native species to produce new species of aggressive polyploid invader? Polyploid plants often have the capacity to produce varied offspring some of which quickly adapt to and dominate, native floras and cultivars alike.
- Is the alien species the host to diseases or parasites communicable to other flora and fauna, man, their crops or domestic animals, in the area of introduction?
- What is the probability that the species to be introduced will threaten the continued existence or stability of populations of native species, whether as a predator, competitor for food, cover, breeding sites or in any other way? If the introduced species is a carnivore, parasite or specialised herbivore, it should not be introduced if its food includes rare native species that could be adversely affected.

b) There are special problems to be considered associated with the introduction of aquatic species. These species have a special potential for invasive spread.

- Many fish change trophic level or diet preference following introduction, making prediction of the results of the re-introduction difficult. Introduction of a fish or other species at one point on a river system or into the sea may lead to the spread of the species throughout the system or area with unpredictable consequences for native animals and plants. Flooding may transport introduced species from one river system to another.
- introduced fish and large aquatic invertebrates have shown a great capacity to disrupt natural systems as their larval, sub-adult and adult forms often use different parts of the same natural system.

c) No introduction should be made for which a control does not exist or is not possible. A risk-and-threat analysis should be undertaken including investigation of the availability of methods for the control of the introduction should it expand in a way not predicted or have unpredicted undesirable effects, and the methods of control should be socially acceptable, efficient, should not damage vegetation and fauna, man, his domestic animals or cultivars.

d)When the questions above have been answered and the problems carefully considered, it should be decided if the species can reasonably be expected to survive in its new habitat, and if so, if it can reasonably be expected to enhance the flora and fauna of the area, or the economic or aesthetic value of the area, and whether these benefits outweigh the possible disadvantages revealed by the investigations.

THE EXPERIMENTAL CONTROLLED TRIAL

Following a decision to introduce a species, a controlled experimental introduction should be made observing the following advice:

- Test plants and animals should be from the same stock as those intended to be extensively introduced.
- They should be free of diseases and parasites communicable to native species, man, his crops and domestic livestock.
- The introduced species' performance on parameters in 'the Assessment Phase' above should be compared with the pre-trial assessment, and the suitability of the species for introduction should be reviewed in light of the comparison.

THE EXTENSIVE INTRODUCTION

If the introduced species behaves as predicted under the experimental conditions, then extensive introductions may commence but should be closely monitored. Arrangements should be made to apply counter measures to restrict, control, or eradicate the species if necessary.

The results of all phases of the introduction operation should be made public and available to scientists and others interested in the problems of introductions.

The persons or organisation introducing the species, not the public, should bear the cost of control of introduced organisms and appropriate legislation should reflect this.

ACCIDENTAL INTRODUCTIONS

1. Accidental introductions of species are difficult to predict and monitor, nevertheless they "should be discouraged where possible. The following actions are particularly important:
    - On island reserves, including isolated habitats such as lakes, mountain tops and isolated forests, and in wilderness areas, special care should be taken to avoid accidental introductions of seeds of alien plants on shoes and clothing and the introduction of animals especially associated with man, such as cats, dogs, rats and mice.
    - Measures, including legal measures, should be taken to discourage the escape of farmed, including captive-bred, alien wild animals and newly-domesticated species which could breed with their wild ancestors if they escaped.
    - In the interest of both agriculture and wildlife, measures should be taken to control contamination of imported agricultural seed with seeds of weeds and invasive plants.
    - Where large civil engineering projects are envisaged, such as canals, which

would link different biogeographical zones, the implications of the linkage for mixing the fauna and flora of the two regions should be carefully considered. An example of this is the mixing of species from the Pacific and Caribbean via the Panama Canal, and the mixing of Red Sea and Mediterranean aquatic organisms via the Suez Canal. Work needs to be done to consider what measures can be taken to restrict mixing of species from different zones through such large developments.

2. Where an accidentally introduced alien successfully and conspicuously propagates itself, the balance of its positive and negative economic and ecological effects should be investigated. If the overall effect is negative, measures should be taken to restrict its spread.

WHERE ALIEN SPECIES ARE ALREADY PRESENT

1. In general, introductions of no apparent benefit to man, but which are having a negative effect on the native flora and fauna into which they have been introduced, should be removed or eradicated. The present ubiquity of introduced species will put effective action against the majority of invasives beyond the means of many States but special efforts should be made to eradicate introductions on:
    - islands with a high percentage of endemics in the flora and fauna;
    - areas which are centres of endemism;
    - areas with a high degree of species diversity;
    - areas with a high degree of other ecological diversity;
    - areas in which a threatened endemic is jeopardised by the presence of the alien.

2. Special attention should be paid to feral animals. These can be some of the most aggressive and damaging alien species to the natural environment, but may have value as an economic or genetic resource in their own right, or be of scientific interest. Where a feral population is believed to have a value in its own right, but is associated with changes in the balance of native vegetation and fauna, the conservation of the native flora and fauna should always take precedence. Removal to captivity or domestication is a valid alternative for the conservation of valuable feral animals consistent with the phase of their evolution as domestic animals.

    Special attention should be paid to the eradication of mammalian feral predators from areas where there are populations of breeding birds or other important populations of wild fauna. Predatory mammals are especially difficult, and sometimes impossible to eradicate, for example, feral cats, dogs, mink, and ferrets.

3. In general, because of the complexity and size of the problem, but especially where feral mammals or several plant invaders are involved, expert advice should be sought on eradication.

BIOLOGICAL CONTROL

1. Biological control of introductions has shown itself to be an effective way of controlling and eradicating introduced species of plants and more rarely, of animals. As biological control involves introduction of alien species, the same care and procedures should be used as with other intentional introductions.

MICRO-ORGANISMS

1. There has recently been an increase of interest in the use of micro-organisms for a wide variety of purposes including those genetically altered by man.
   Where such uses involve the movement of micro-organisms to areas where they did not formerly exist, the same care and procedures should be used as set out above for other species.

PART II

THE RE-INTRODUCTION OF SPECIES *

Re-introduction is the release of a species of animal or plant into an area in which it was indigenous before extermination by human activities or natural catastrophe. Re-introduction is a particularly useful tool for restoring a species to an original habitat where it has become extinct due to human persecution, over-collecting, over-harvesting or habitat deterioration, but where these factors can now be controlled. Re-introductions should only take place where the original causes of extinction have been removed. Re-introductions should only take place where the habitat requirements of the species are satisfied. There should be no re-introduction if a species became extinct because of habitat change which remains unremedied, or where significant habitat deterioration has occurred since the extinction.

The species should only be re-introduced if measures have been taken to reconstitute the habitat to a state suitable for the species.

The basic programme for re-introduction should consist of:

- a feasibility study;
- a preparation phase;
- release or introduction phase; and a
- follow-up phase.

THE FEASIBILITY STUDY

An ecological study should assess the previous relationship of the species to the habitat into which the re-introduction is to take place, and the extent that the habitat has changed since the local extinction of the species. If individuals to be re-introduced have been captive-bred or cultivated, changes in the species should also be taken into account and allowances made for new features liable to affect the ability of the animal or plant to re-adapt to its traditional habitat.

The attitudes of local people must be taken into account especially if the reintroduction of a species that was persecuted, over-hunted or over collected , is proposed. If the attitude of local people is unfavorable an education and interpretive programme emphasizing the benefits to them of the re-introduction, or other inducement, should be used to improve their attitude before re-introduction takes place.

The animals or plants involved in the re-introduction must be of the closest available race or type to the original stock and preferably be the same race as that previously occurring in the area.

Before commencing a re-introduction project, sufficient funds must be available to ensure that the project can be completed, including the follow-up phase.

THE PREPARATION AND RELEASE OR INTRODUCTORY PHASES

The successful re-introduction of an animal or plant requires that the biological needs of the species be fulfilled in the area where the release is planned. This requires a detailed knowledge of both the needs of the animal or plant and the ecological dynamics of the area of re-introduction. For this reason the best available scientific advice should be taken at all stages of a species re-introduction.

This need for clear analysis of a number of factors can be clearly seen with reference to introductions of ungulates such as ibex, antelope and deer where re-introduction involves understanding and applying the significance of factors such as the ideal age for re-introducing individuals, ideal sex ratio, season, specifying capture techniques and mode of transport to re-introduction site, freedom of both the species and the area of introduction from disease and parasites, acclimatisation, helping animals to learn to forage in the wild, adjustment of the gut flora to deal with new forage, 'imprinting' on the home range, prevention of wandering of individuals from the site of re-introduction, and on-site breeding in enclosures before release to expand the released population and acclimatise the animals to the site. The re-introduction of other taxa of plants and animals can be expected to be similarly complex.

FOLLOW-UP PHASE

Monitoring of released animals must be an integral part of any re-introduction programme. Where possible there should be long-term research to determine the rate of adaptation and dispersal, the need for further releases and identification of the reasons for success or failure of the programme.

The species impact on the habitat should be monitored and any action needed to improve conditions identified and taken.

Efforts should be made to make available information on both successful and unsuccessful re-introduction programmed through publications, seminars and other communications.

PART III

RESTOCKING

1. Restocking is the release of a plant or animal species into an area in which it is already present. Restocking may be a useful tool where:
    - it is feared that a small reduced population is becoming dangerously inbred; or
    - where a population has dropped below critical levels and recovery by natural growth will be dangerously slow; or
    - where artificial exchange and artificially-high rates of immigration are required to maintain outbreeding between small isolated populations on biogeographical islands.
2. In such cases care should be taken to ensure that the apparent nonviability of the population, results from the genetic institution of the population and not from poor species management which has allowed deterioration in the habitat or over-utilisation of the population. With good management of a population the need for re-stocking should be avoidable but where re-stocking is contemplated the following points should be observed:

a) Restocking with the aim of conserving a dangerously reduced population should only be attempted when the causes of the reduction have been largely removed and natural increase can be excluded.

b) Before deciding if restocking is necessary, the capacity of the area it is proposed to restock should be investigated to assess if the level of the population desired is sustainable. If it is, then further work should be undertaken to discover the reasons for the existing low population levels. Action should then be taken to help the resident population expand to the desired level. Only if this fails should restocking be used.

3. Where there are compelling reasons for restocking the following points should be observed.

   a) Attention should be paid to the genetic constitution of stocks used for restocking.

   - In general, genetic manipulation of wild stocks should be kept to a minimum as it may adversely affect the ability of a species or population to survive. Such manipulations modify the effects of natural selection and ultimately the nature of the species and its ability to survive.
   - Genetically impoverished or cloned stocks should not be used to re-stock populations as their ability to survive would be limited by their genetic homogeneity.

   b) The animals or plants being used for re-stocking must be of the same race as those in the population into which they are released.

   c) Where a species has an extensive natural range and restocking has the aim of conserving a dangerously reduced population at the climatic or ecological edge of its range, care should be taken that only individuals from a similar climatic or ecological zone are used since interbreeding with individuals from an area with a milder climate may interfere with resistant and hardy genotypes on the population's edge.

   d) Introduction of stock from zoos may be appropriate, but the breeding history and origin of the animals should be known and follow as closely as possible Assessment Phase guidelines a, b, c and d (see pages 5-7). In addition the dangers of introducing new diseases into wild populations must be avoided: this is particularly important with primates that may carry human zoonoses.

   e) Restocking as part of a sustainable use of a resource (e.g. release of a proportion of crocodiles hatched from eggs taken from farms) should follow guidelines a and b (above).

   f) Where restocking is contemplated as a humanitarian effort to release or rehabilitate captive animals it is safer to make such releases as re-introductions where there is no danger of infecting wild populations of the same species with new diseases and where there are no problems of animals having to be socially accepted by wild individuals of the species.

PART IV

NATIONAL, INTERNATIONAL AND SCIENTIFIC IMPLICATIONS OF TRANSLOCATIONS

NATIONAL ADMINISTRATION

1. Pre-existing governmental administrative structures and frameworks already in use to protect agriculture, primary industries, wilderness and national parks should be used by governments to control both intentional and unintentional importation of organisms, especially through use of plant and animal quarantine regulations.
2. Governments should set up or utilise pre-existing scientific management authorities or experts in the fields of biology, ecology and natural resource management to advise them on policy matters concerning translocations and on individual cases where an introduction, re-introduction or restocking or farming of wild species is proposed.
3. Governments should formulate national policies on:
    - translocation of wild species;
    - capture and transport of wild animals;
    - artificial propagation of threatened species;
    - selection and propagation of wild species for domestication; and
    - prevention and control of invasive alien species.
4. At the national level legislation is required to curtail introductions:

    Deliberate introductions should be subject to a permit system. The system should apply not only to species introduced from abroad but also to native species introduced to a new area in the same country. It should also apply to restocking.

    Accidental introductions

    - for all potentially harmful organisms there should be a prohibition to import them and to trade in them except under a permit and under very stringent conditions. This should apply in particular to the pet trade;
    - where a potentially harmful organism is captive bred for commercial purposes (e.g. mink) there should be established by legislation strict standards for the design and operation of the captive breeding facilities. In particular, procedures should be established for the disposal of the stock of animals in the event of a discontinuation of the captive breeding operation;
    - there should be strict controls on the use of live fish bait to avoid inadvertent introductions of species into water where they do not naturally occur.

    Penalties

5. Deliberate introductions without a permit as well as negligence resulting in the escape or introduction of species harmful to the environment should be considered criminal offences and punished accordingly. The author of a deliberate introduction without a permit or the person responsible for an introduction by negligence should be legally liable for the damage incurred and should in particular bear the costs of eradication measures and of habitat restoration where required.

INTERNATIONAL ADMINISTRATION

Movement of Introduced Species Across International Boundaries

1. Special care should be taken to prevent introduced species from crossing the borders of a neighboring state. When such an occurence is probable, the neighboring state should be promptly warned and consultations should be held in order to take adequate measures.

The Stockholm Declaration

2. According to Principle 21 of the Stockholm Declaration on the Human Environment, states have the responsibility 'to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states'.

International Codes of Practice, Treaties and Agreements

3. States should be aware of the following international agreements and documents relevant to translocation of species:
    - ICES, Revised Code of Practice to Reduce the Risks from introduction of Marine Species, 1982.
    - FAO, Report of the Expert Consultation on the Genetic Resources of Fish, Recommendations to Governments No L 1980.
    - EIFAC (European Inland Fisheries Advisory Commission), Report of the Working Party on Stock Enhancement, Hamburg, FRG 1983.
    - The Bonn Convention MSC: Guidelines for Agreements under the Convention.
    - The Berne Convention: the Convention on the Conservation of European wildlife and Natural Habitats.
    - The ASEAN Agreement on the Conservation of Nature and Natural Resources.
    - Law of the Sea Convention, article 196.
    - Protocol on Protected Areas and Wild Fauna and Flora in Eastern African Region.

    In addition to the international agreements and documents cited, States also should be aware of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). International shipments of endangered or threatened species listed in the Appendices to the Convention are subject to CITES regulation and permit requirements. Enquiries should be addressed to: CITES Secretariat **, Chèmin des Anèmones, 1219 Chatelaine, Geneva, Switzerland; telephone: 41/22/979 9139 or 9140, fax: 41/22/797 3417, e-mail: *cites@unep.ch*.

Regional Development Plans

4. International, regional or country development and conservation organisations, when considering international, regional or country conservation strategies or plans, should include in-depth studies of the impact and influence of introduced alien species and recommend appropriate action to ameliorate or bring to an end their negative effects.

Scientific Work Needed

5. A synthesis of current knowledge on introductions, re-introductions and re-stocking is needed.

6. Research is needed on effective, target specific, humane and socially acceptable methods of eradication and control of invasive alien species.

7. The implementation of effective action on introductions, re-introductions and re-stocking frequently requires judgements on the genetic similarity of different stocks of a species of plant or animal. More research is needed on ways of defining and classifying genetic types.
8. Research is needed on the way in which plants and animals are dispersed through the agency of man (dispersal vector analysis).

   A review is needed of the scope, content and effectiveness of existing legislation relating to introductions.

   IUCN Responsibilities

   International organisations, such as UNEP, UNESCO and FAO, as well as states planning to introduce, re-introduce or restock taxa in their territories, should provide sufficient funds, so that IUCN as an international independent body, can do the work set out below and accept the accompanying responsibilities.
9. IUCN will encourage collection of information on all aspects of introductions, re-introductions and restocking, but especially on the case histories of re-introductions; on habitats especially vulnerable to invasion; and notable aggressive invasive species of plants and animals.

   Such information would include information in the following categories:

   - a bibliography of the invasive species;
   - the taxonomy of the species;
   - the synecology of the species; and
   - methods of control of the species.
10. The work of the Threatened Plants Unit of IUCN defining areas of high plant endemism, diversity and ecological diversity should be encouraged so that guidance on implementing recommendations in this document may be available.
11. A list of expert advisors on control and eradication of alien species should be available through IUCN.

Note:
* The section on re-introduction of species has been enhanced by the Guidelines for Re-introductions

** The address of the CITES Secretariat has been updated.

IUCN Guidelines for the Placement of Confiscated Animals

Prepared by the

IUCN/SSC Re-introduction Specialist Group

IUCN

The World Conservation Union

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ERWDA

RSG

SPECIES SURVIVAL COMMISSION

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Environmental Research & Wildlife Development Agency (ERWDA)

ERWDA was established by Law No. 4 of 1996 and amended by Law No. 1 of 1997 by H.H. Sheikh Khalifa Bin Zayed Al Nahyan, Crown Prince of Abu Dhabi, Deputy Supreme Commander of the Armed Forces.

ERWDA's Mission is to assist the Abu Dhabi Government in the conservation and management of the Emirate's natural environment, resources, wildlife and biological diversity. This is to be done through scientific research, proactive planning and coordination, environmental awareness promotion, policy formulation, and enforcement that balances sustainable economic development with the protection of the environment for this and future generations.

IUCN - The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 935 members in all, spread across some 138 countries.

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.

The World Conservation Union builds on the strengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels.

IUCN GUIDELINES FOR THE PLACEMENT OF CONFISCATED ANIMALS

EXECUTIVE SUMMARY

Live wild animals are confiscated by local, regional, and national authorities for a variety of reasons. Once they have taken possession of these animals, these authorities must dispose of them responsibly, in a timely and efficient manner. Prevailing legislation, cultural practices, and economic conditions will influence decisions on appropriate disposition of confiscated animals. Within a conservation context, there are several possible options from which to choose:

1) to maintain the animals in captivity for the remainder of their natural lives;
2) to return the animals to the wild;
3) to euthanize the animals, i.e., humanely destroy them

The IUCN Guidelines for the Placement of Confiscated Animals discuss the benefits and risks involved in each of these options. These Guidelines should be read in conjunction with the IUCN Guidelines for Re-introductions (IUCN 1998), annexed hereto. They should also be read with reference to the CITES Guidelines for the Disposal of Confiscated Live Species of Species Included in the Appendices (Resolution Conf. 10.7) and the IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion.

Returning confiscated animals to the wild is often considered the most popular option for a confiscating agency and can garner strong public support. However, such action poses real risks and problems and generally confers few benefits. These risks and problems include, but are not limited to, the following.

1. The mortality of animals released from captivity is usually high. Confiscated mammals and birds captured as juveniles have not learned the skills they need to survive in the wild. Other animals may be weakened or otherwise affected by their time in captivity and, thus, less able to survive. Finally, there is little chance of survival if the animals are released at a site that is not appropriate for the ecology or behavior of the species.
2. Animals released into the wild outside of their natural range – if they survive at all – have the potential to become pests or invasive. The effects of invasive alien species are a major cause of biodiversity loss, as such species compete with native species and in other ways compromise the ecological integrity of the habitats in which they have become established.
3. Having been in trade or a holding facility often in association with other wild animals and, in some instances, domesticated ones, confiscated wild animals are likely to have been exposed to diseases and parasites. If returned to the wild, these animals may infect other wild animals, thus causing serious, and potentially irreversible, problems.
4. In many instances, confiscated wild animals have been moved great distances from the site of capture and changed hands several times, such that their actual provenance is unknown. It may, therefore, be impossible or very difficult to establish an appropriate site for return to the wild that takes into account the ecological needs of the species, the animals' genetic make-up, and other attributes that are important to minimize risks (e.g., competition, hybridization) to wild populations at a release site.
5. in cases where the provenance is known, the ecological niche vacated by that animal may already be filled by other individuals and replacing the animal could result in further undesired disturbance of the ecosystem
6. Responsible programs to return animals to the wild (c.f. IUCN 1998) are long-term endeavors that require substantial human and financial resources; hence, they can divert scarce resources away from other more effective conservation activities.

If returning confiscated animals to the wild is to be consistent with conservation principles and practice, it should a) *only* be into a site outside of the species' natural range if such an action is in accordance with the IUCN Guidelines for Re-introductions for a conservation introduction; and b) only be practiced in cases where the animals are of high conservation value and/or the release is part of a management programme. Any release to the wild must include the necessary screening and monitoring to address potential negative impacts, as set forth in the IUCN Guidelines for Re-introductions (IUCN 1998).

Retaining confiscated wild animals in captivity is a clear – and, in most cases, preferable - alternative to returning them to the wild. Clearly, returning animals to their owners will be required in cases of theft. There are a number of options for keeping animals in captivity; however, each of these also has costs and risks.

- As confiscated animals are likely to have been exposed to diseases and parasites, if held in captivity, they may infect other captive animals, causing serious, and potentially irreversible, problems.
- Finding an appropriate home for confiscated animals can be time-consuming, and caring for the animals during that time can be expensive.
- Wild animals have specific nutritional requirements and require specific care. Short-term and long-term humane care of confiscated wild animals requires space, finances and expertise not readily available in many countries.
- Transfer of ownership from a confiscating government authority to a private entity – individual or non-commercial or commercial care facility – can raise complicated legal and ethical issues, which are difficult – and time-consuming - to address. Sale or transfer of ownership may – or may be seen to - stimulate demand for these animals and exacerbate any threat that trade may pose to the species. It may also give the appearance that the government condones illegal or irregular trade or, in the case of actual sale, is benefiting from such trade.

In addition to avoiding risks to wild populations engendered by return to the wild, keeping confiscated animals in captivity provides other benefits, for example:

- Confiscated animals can be used to educate people about wildlife and conservation, as well as the consequences of trade in live wildlife.
- Confiscated animals placed in captivity can provide breeding stock for zoos, aquariums, and other facilities, thus potentially reducing the demand for wild-caught animals although the opposite effect may also occur.
- In specific instances where the provenance of the confiscated specimens is known, these animals can provide the nucleus, and breeding stock, for possible reintroduction programs.
- Confiscated animals can be the subject of a range of non-invasive research, training and teaching programs with important potential benefits for conservation.

Euthanasia must be considered a valid alternative to placing animals in captivity or returning them to the wild. Although it may appear counter-intuitive to employ euthanasia, it is by definition a humane act and can be wholly consistent with both conservation and animal welfare considerations. Further, although many confiscating authorities may be wary of criticism elicited by a decision to euthanize confiscated animals, there are a number of reasons to justify its use, including the following:

- In many, if not most, circumstances, euthanasia offers the most humane alternative for dealing with confiscated wild animals.

- Euthanasia eliminates the genetic, ecological, and other risks that release to the wild may pose to wild populations and ecosystems.
- Euthanasia eliminates the serious risk of spreading disease to wild or captive populations of animals.
- Euthanasia will often be the least costly option.

Establishment of an overall policy framework, with specific procedures for confiscating authorities, will facilitate consideration of the above three options for disposition, including the logistical, legal, and ethical questions that these authorities must address.

IUCN Guidelines for the Placement of Confiscated Animals

Statement of Principle

When live wild animals[1] are confiscated by government authorities, these authorities have a responsibility to dispose of them appropriately. Within a conservation context, and the confines of national and international law, the ultimate decision on placement of confiscated animals must achieve three goals: 1) to maximise the conservation value of the animals without in any way endangering the health, behavioural repertoire, genetic characteristics, or conservation status of wild or captive populations of the species[2] or any other wild living organism; 2) to discourage further illegal or irregular[3] trade in the species; and 3) to provide a humane solution, whether this involves maintaining the animals in captivity, returning them to the wild, or employing euthanasia to destroy them.

Statement of Need

Increased regulation of trade in wildlife and enforcement of these laws and regulations have resulted in an increase in the number of live wild animals that are confiscated by government agencies as a result of non-compliance with these regulations. In some instances, the confiscation is a result of patently illegal trade; in others, it is in response to other irregularities. While in some cases the number of confiscated animals is small, in many others the number is in the hundreds or greater. The large numbers involved, and the need to care for and dispose of them responsibly, have placed serious pressures on confiscating authorities, many of whom lack the technical, financial or human resources or the necessary frameworks to address these situations adequately.

In many countries, the practice has generally been to donate confiscated[4] animals to zoos or aquaria. However, this option is proving less viable. Zoos and aquaria generally cannot accommodate large numbers of animals that become available through confiscations. In addition to the resources required to house them and administer veterinary and other care, these institutions are usually less interested in the common species that comprise the vast proportion of wildlife confiscations. The international zoo community has recognized that placing animals of low conservation priority in limited cage space may benefit those individuals but may also detract from conservation efforts as a whole. Therefore, they are setting priorities for cage space (IUDZG/CBSG 1993), thus reducing their availability to receive confiscated animals.

There has been an increasing tendency to address the problem of disposition of confiscated animals by releasing them back into the wild. In some cases, release of confiscated animals into existing wild populations has been made after careful evaluation and with due regard for existing general guidelines (IUCN 1987, IUCN 1998). In other cases, such releases have not been well planned and have been inconsistent with general conservation objectives and

[1]In these Guidelines, unless stated otherwise, confiscated animals should be understood to refer to live wild animals, not those that have been captive-bred.
[2]Although this document refers to species, in the case of species with well-defined subspecies , the issues addressed will apply to lower taxonomic units.
[3]Irregular trade in a species refers to, for example, insufficient or incomplete paperwork from the exporting country or poor packing that has comprised the welfare of the live animals in the shipment.
[4]Although not discussed here, it should be understood that, depending on the statutory authority of the agencies involved, animals may first be seized and then confiscated only on completion of legal proceedings resulting in forfeiture by the individual having previously claimed ownership of the animals.

humane considerations. Animals released in inappropriate habitat are usually doomed to starvation or death from other causes that the animals are not equipped or adapted against. In addition to humane concerns, release into wild populations may also have strong negative conservation value by threatening existing wild populations for the following reasons.

1) Animals released into the wild outside their natural range can become pests or invasive, thus threatening agriculture and other sectors, native species, and the ecological integrity of the area in which they become established. The effects of invasive alien species are a major cause of global biodiversity loss.
2) The former home range of a confiscated animal may be quickly occupied by other individuals and releasing the confiscated animal could lead to further disruption of the animal's social ecology.
3) Diseases and parasites acquired by confiscated animals while held in captivity can easily spread into existing wild populations if these animals are released.
4) Individuals released into existing populations, or in areas near to existing populations, that are not of the same race or sub-species as those in the wild population, results in mixing of distinct genetic lineages.
5) Animals held in captivity, particularly immature animals, can acquire an inappropriate behavioural repertoire from individuals of other species, and/or lose certain behaviours or not develop the full behavioural repertoire necessary for survival in the wild. It is also possible that release of animals could result in inter-specific hybridisation, a problem also to be avoided.

In light of these trends, there is an increasing demand -- and urgent need -- for information and advice on considerations relating to responsible placement of confiscated animals. There is also a pressing need for technical expertise and assistance in assessing the veterinary, husbandry and other questions that must be addressed in this process. Recognizing this problem, the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have adopted guidelines for Disposal of Confiscated Live Specimens of Species Included in the Appendices (Resolution Conf. 10.7), applicable to both plants and animals. These IUCN guidelines build on and supplement those drawn up by CITES to apply more broadly to confiscated animals and confiscation situations.

Disposition of confiscated animals is not a simple or straightforward process. Only on rare occasions will the optimum course be obvious or result in an action of conservation value. Options for disposition of confiscated animals have thus far been influenced by the public's perception that returning animals to the wild is the optimal solution in terms of both animal welfare and conservation. However, a growing body of scientific study of re-introduction of captive animals, the nature and dynamics of wildlife diseases, and the nature and extent of the problems associated with invasive species suggests that such actions may be among the least appropriate options for many reasons, including those enumerated above. This recognition requires that the options available to confiscating authorities for disposition be carefully reviewed.

Management Options

In deciding on the disposition of confiscated animals, there is a need to ensure both the humane treatment of the animals and the conservation and welfare of existing wild populations. Options for disposition fall into three principal categories: 1) maintenance of the individual(s) in captivity; 2) returning the individual(s) in question to the wild; and 3) euthanasia.

Within a conservation perspective, by far the most important consideration in reviewing the options for disposition of confiscated animals is the conservation status of the species concerned. Where the animals represent an endangered or threatened species or are otherwise of high conservation value[5], particular effort should be directed towards evaluating whether and how these animals might contribute to a conservation programme for the species. The expense and difficulty of returning animals to the wild as part of a conservation (c.f. IUCN 1998, presented in Annex 4) or management programme or pursuing certain captive options will generally only be justified for species of high conservation value. How to allocate resources to the large numbers of confiscated animals representing common species is one of the fundamental policy questions that confiscating authorities must address.

The decision as to which option to employ in the disposition of confiscated animals will depend on various legal, social, economic and biological factors. The "Decision Tree" provided in the present guidelines is intended to facilitate consideration of these options. The tree has been designed so that it may be used for both threatened and common species. However, it recognizes that that conservation value of the species will be the primary consideration affecting the options available for placement. International networks of experts, such as the IUCN Species Survival Commission Specialist Groups (see Annex 3 for contact details), should be able to assist confiscating authorities in their deliberations as to the appropriate disposition of confiscated animals.

In some instances, in the case of international trade, there may be a demand for confiscated animals to be returned to their country of origin, and the government authorities of that country may request their return. CITES has established guidelines on this question through Resolution Conf. 10.7. It should be noted that it is often difficult to establish the true origin (including country of origin) of many animals in trade. Moreover, final disposition of confiscated animals upon their return to the country of origin will require consideration of the same options presented here. There is a need for cooperative efforts to review these options in order to ensure that repatriation is not undertaken simply to shift the burden of addressing the problem to the country of origin.

Option 1 -- Captivity

Confiscated animals are already in captivity; there are numerous options for maintaining them there. Depending on the circumstances and the prevailing legal or policy prescriptions, animals. can be donated, loaned, or sold, to public or private facilities, commercial or non-commercial, and to private individuals. Placement can be in the country of origin (or export), country of confiscation, or a country with adequate and/or specialized facilities for the species or animals in question. If animals are maintained in captivity, in preference to being returned to the wild or euthanized, they must be afforded humane conditions and ensured proper care for their natural lives.

Zoos and aquaria are the captive facilities most commonly considered for placement of animals, but these institutions are generally less willing and available to receive such animals than is assumed. As most confiscated animals are common species, the full range of captive options should be considered. These include zoos and aquaria as well as the following:

- **Rescue centers**, established specifically to treat injured or confiscated animals;
- **Life-time care facilities** devoted to the care of confiscated animals;
- **Specialist societies** or clubs devoted to the study and care of single species or species

[5] It is recognized that “conservation value” may not always be easy to assess and may be a function of species’ status at national or regional level as much as international level (e.g., listed as threatened by IUCN).

groups (e.g., reptiles, amphibians, birds) have provided an avenue for the disposition of confiscated animals through placement with these societies or individual members.

- **Humane societies** established to care and seek owners for abandoned animals may be in a position to assist with placement of confiscated animals with private individuals who can provide life-time care.

- **Commercial captive breeders** may be willing to receive and care for animals as well as to incorporate them into captive breeding activities. Such facilities, although commercial in nature, are likely to have the technical expertise and other resources to care for the animals. In addition, production of animals from captive breeding operations may reduce the demand for wild-caught animals.

- **Research institutions** maintain collections of exotic animals for many kinds of research (e.g. behavioural, ecological, physiological, psychological, medical and veterinary). Some research programmes have direct relevance to conservation. Attitudes towards vivisection or, in some instances, the non-invasive use of animals in research programmes as captive study populations vary widely from country to country and even within countries. These attitudes are likely to affect consideration of such programmes as an option for confiscated animals. However, it should be noted that transfer to facilities involved in research conducted under humane conditions may offer an alternative - and one that may eventually contribute information relevant to the species' conservation.

Choosing amongst these options will depend on the conservation value of the animals involved, the condition of the animals, the circumstances of trade in the species, and other factors. As a general rule, where confiscated animals are of high conservation value, an effort should be made to place them in a captive facility that ensures their availability for conservation efforts over the long term, such as with a zoo, ex-situ research programme, or an established captive breeding program or facility.

Captivity – Sale, Loan or Donation

Animals can be placed with an institution or individual in a number of ways. It is critical to consider two issues: the ownership of the animals and/or their progeny, and the payment of any fees as part of transfer of ownership. Confiscating authorities and individuals or organizations involved in the placement of confiscated specimens must clarify ownership, both of the specimens being transferred and any progeny. They must also consider the possible implications of payment of fees in terms of public perception and for achieving the purpose of confiscation, which is to penalize and, in so doing, deter illegal and irregular trade. The following points should considered.

Transfer of ownership/custody**.** Unless specific legal provisions apply, the confiscating authority should consider including in an agreement to transfer ownership or custody the conditions under which the transfer is made, such as any restrictions on use (e.g., exhibition, education, captive breeding, commercial or non-commercial) or obligations concerning use (breeding efforts), that the animals may be put to. Such an agreement may set forth conditions relating to:

- subsequent transfer of ownership or custody;
- changes in the use of the animals by the new owner or custodian; and
- consequences of violation of the terms of transfer by the new owner or custodian.

Payment of fees. There may be cases where captive facilities are willing to receive and commit to care for confiscated animals providing payment is made by the confiscating authority against those costs. More frequently, the confiscating authority may seek to recoup the costs of caring for the animals prior to placement by levying a fee as part of transfer of ownership. Such payment of fees is problematic for many reasons, including the following:

- it may weaken the impact of the confiscation as a deterrent;
- it may risk creating a public perception that the confiscating authority is perpetuating or benefiting from illegal or irregular trade; or
- depending on the level of the fees proposed, it may work against finding a suitable option for maintaining the animals in captivity.

It is important that confiscating authorities be prepared to make public the conditions under which ownership of confiscated animals has been transferred and, where applicable, the basis for any payments involved.

Captivity – Benefits

In addition to avoiding the risks associated with attempting to return them to the wild, there are numerous benefits of placing confiscated animals in a facility that will provide life-time care under humane conditions. These include:

a) educational value in terms of possible exhibition or other use;
b) the satisfaction to be derived from the increased chances for survival of the animals;
c) the potential for the animals to be used in a captive breeding programme to replace wild-caught animals as a source for trade;
d) the potential for captive breeding for possible re-introduction or other conservation programmes; and
e) the potential for use in conservation and other valuable research programs.

Captivity - Concerns

The concerns raised by placing animals in captivity include:

A) DISEASE. Confiscated animals may serve as vectors for disease, which can affect con-specifics and other species held in captivity. As many diseases cannot be screened for, even the strictest quarantine and most extensive screening for disease cannot ensure that an animal is disease-free. Where quarantine cannot adequately ensure that an individual is disease-free, isolation for an indefinite period, or euthanasia, must be carried out.

B) CAPTIVE ANIMALS MAINTAINED OUTSIDE THEIR RANGE CAN ESCAPE from captivity and become pests or invasive. Unintentionally introduced exotic species have become invasive in many countries, causing tremendous damage to agriculture, fisheries, and transport, but also to native animal populations. The decline of the European mink (*Mustela lutreola*), listed as Endangered by IUCN, is in part a result of competition from American mink (*Mustela vison*) escaped from fur farms, while the negative effects of competition from introduced North American red-eared slider turtles (*Trachemys scripta elegans)*, originally imported as pets, have been raised in relation to European and Asian freshwater turtles.

C) COST OF PLACEMENT. Providing housing and veterinary and other care to confiscated animals can be expensive; as a result, it may be difficult to identify institutions or individuals willing to assume these costs.

D) POTENTIAL TO ENCOURAGE UNDESIRED TRADE. As is discussed above, transfer of ownership of confiscated animals to individuals or institutions, whether it involves loan, donation, or sale, is problematic. Some have argued that any transfer of ownership - whether commercial or non-commercial - of confiscated animals risks promoting a market for these species and creating a perception of the confiscating authority's being involved in illegal or irregular trade. These risks must be weighed in relation to the benefits, in particular that maintenance in captivity offers over return to the wild or euthanasia. Some factors that might be considered in assessing the degree to which transfer of ownership – and sale - might promoted undesired trade are:

1) whether the animals in question are already available for sale legally in the confiscating country in commercial quantities; and
2) whether wildlife traders under indictment for, or convicted of, crimes related to illegal or irregular trade in wildlife can be prevented from purchasing the animals in question.
3) the monetary/ commercial value of the animals in question

As regards the latter question, it should be noted that experience in selling confiscated animals suggests that it is virtually impossible to ensure that commercial dealers suspected or implicated in illegal or irregular trade are excluded, directly or indirectly, in purchasing confiscated animals.

In certain circumstances, transfer to commercial captive breeders may have a clearer potential for the conservation of the species, or welfare of the individuals, than non-commercial disposition or euthanasia. In the case of common species, commercial breeders may be a particularly attractive option; in the case of species of high conservation value, this option should be carefully assessed. There may be a risk of stimulating demand from wild populations through increased availability of the species, and it may be difficult to secure access to these animals for future conservation activities.

Option 2 -- Return to the Wild

Because of the serious risks posed to wild animal populations from released confiscated animals, return to the wild is considered here to be a desirable option in only a very small number of instances and under very specific circumstances. The IUCN Guidelines for Re-introductions (IUCN 1998, reproduced in Annex 4) make a clear distinction between the different options for returning animals to the wild to meet conservation objectives and discuss the purposes, rationale and procedures relating to these options.

The present Guidelines do not consider a viable option the return of animals to the wild except in accordance with the IUCN Guidelines for Re-introductions. Poorly planned or executed release or (re-)introduction programmes are no better than dumping animals in the wild and should be vigorously opposed on both conservation and humane grounds.

A) **Re-introduction**: an attempt to establish a population in an area that was once part of the range of the species but from which it has become extirpated.

Some of the best known re-introductions have been of species that had become extinct in the wild. Examples include: Père David's deer (*Elaphurus davidanus*) and the Arabian oryx (*Oryx leucoryx*). Other re-introduction programmes have involved species that persist in some parts of their historical range but have been eliminated from others; the aim of these programmes is to re-establish a population in an area, or region, from which the species has disappeared. An example of this type of re-introduction is the recent re-introduction of the swift fox (*Vulpes velox*) in Canada.

B) **Reinforcement of an Existing Population** (also referred to as Supplementation): the addition of individuals to an existing population of the same species.

Reinforcement can be a powerful conservation tool when natural populations are diminished by a process which, at least in theory, can be reversed. One of the few examples of a successful reinforcement project involves the golden lion tamarin (*Leontopithecus rosalia*) in Brazil. Habitat loss, coupled with capture of live animals for pets, resulted in a rapid decline of the golden lion tamarin. When reserves were expanded, and capture for trade curbed, captive-bred golden lion tamarins were then used to supplement depleted wild populations.

Reinforcement has been most widely pursued in the context of rehabilitation programmes, i.e., when individual injured animals have been provided with veterinary care and released. Such activities are common in many countries, and specific programmes exist for species as diverse as hedgehogs and birds of prey. However common an activity, reinforcement carries with it the very grave risk that individuals held in captivity, even temporarily, are potential vectors for the introduction of disease or infectious organisms into wild populations.

Because of disease and other risks to wild populations, as well as the costs of screening and post-release monitoring, reinforcement should only be employed in instances where there is a direct and measurable conservation benefit (demographically and/or genetically, and/or to enhance conservation in the public's eye), or, at least, where the presumed benefits clearly outweigh these risks.

C) **Conservation Introductions** (also referred to as Beneficial or Benign Introductions): an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species' historic range.

Extensive use of conservation introductions has been made in New Zealand, where endangered birds have been transferred to off-shore islands that were adjacent to, but not part of, the animals' original range. Conservation introductions can also be a component of a larger programme of re-introduction, an example being the breeding of red wolves (*Canis rufus*) on islands outside their natural range and subsequent transfer to mainland range areas.

Return to the Wild - Benefits

There are benefits of returning confiscated animals to the wild, providing the pre-requisite veterinary, genetic, and other screening is undertaken and post-release monitoring programmes are established (as per IUCN 1998).

a) In situations where the existing population is severely threatened, re-introduction might improve the long-term conservation potential of the species as a whole, or of a local population of the species (e.g., golden lion tamarins).

b) Return to the wild makes a strong political/educational statement concerning the fate of animals and may serve to promote local conservation values. However, as part of any education or public awareness programmes, the costs and difficulties associated with the return to the wild must be emphasized.

c) Species returned to the wild have the possibility of continuing to fulfill their biological and ecological roles.

Return to the Wild - Concerns

As indicated above, because of the risk of biological invasion, these guidelines do not consider it a viable option to return animals to the wild outside of their natural range in any but the most exceptional circumstances. Before return to the wild (as per IUCN 1998) of confiscated animals is considered, several issues of concern must be considered in general terms: welfare, conservation value, cost, and disease.

A) WELFARE. While some consider return to the wild to be humane, ill-conceived projects may return animals to the wild which then die from starvation or do not adapt to an unfamiliar or inappropriate environment. Humane considerations require that each effort to return confiscated animals to the wild be thoroughly researched and carefully planned. Re-introduction projects also require long-term commitment in terms of monitoring the fate of released individuals.

In order for return to the wild to be seriously considered on welfare grounds, some have advocated that the survival prospects for released animals must at least approximate those of wild animals of the same sex and age. While such demographic data on wild populations are rarely available, the spirit of this suggestion should be respected -- there must be humane treatment of confiscated animals when attempting to return them to the wild, and there should be a reasonable assessment of the survival prospects of the animals to justify the risks involved.

B) CONSERVATION VALUE AND COST. In cases where returning confiscated animals to the wild appears to be the most humane option, such action can only be undertaken if it does not threaten existing populations of con-specifics or populations of other interacting species, or the ecological integrity of the area in which they live. The conservation of the species as a whole, and of other animals already living free, must take precedent over the welfare of individual animals that are already in captivity.

Before animals are used in programmes in which existing populations are reinforced, or new populations are established, it must be determined that returning these individuals to the wild will make a significant contribution to the conservation of the species, or populations of other interacting species, or it must serve a purpose directly related to the conservation and management of the species or ecosystem involved. Based solely on demographic considerations, large populations are less likely to go extinct, and, therefore, reinforcing existing very small wild populations may reduce the probability of extinction. In very small populations, a lack of males or females may result in reduced population growth or population decline and, therefore, reinforcing a very small population lacking animals of a particular sex may also improve prospects for survival of that population. However, genetic and behavioural considerations, as well as the possibility of disease introduction, also play a fundamental role in determining the long-term survival of a population. The potential conservation benefit of the re-introduction should clearly outweigh the risks.

The cost of returning animals to the wild in a responsible manner can be prohibitive, suggesting that this option should only be pursued when species are of high conservation value. Exceptions to this rule may be instances where the confiscated animals are not of high conservation value, but the circumstances and technical and other resources are available to ensure re-introduction is undertaken in accordance with conservation guidelines (e.g., IUCN 1998)

C) DISEASE. Animals held in captivity and/or transported, even for a very short time, may be exposed to a variety of pathogens. Release of these animals to the wild may result in introduction of disease to con-specifics or unrelated species with potentially catastrophic effects. Even if there is a very small risk that confiscated animals have been infected by exotic pathogens, the potential effects of introduced diseases on wild populations are often so great that this should preclude returning confiscated animals to the wild.

Release into the wild of any animal that has been held in captivity is risky. Animals held in captivity are more likely to acquire diseases and parasites. While some of these diseases can be tested for, tests do not exist for many animal diseases. Furthermore, animals held in captivity are frequently exposed to diseases not usually encountered in their natural habitat. Veterinarians and quarantine officers, thinking that the species in question is only susceptible to certain diseases, might not test for the diseases picked up in captivity. It should be assumed that all diseases are potentially contagious.

In assessing the possibilities for disease, it may be particularly helpful to consider the known or presumed circumstances of trade, including:

a) the time and distance from point of capture; the number of stages of trade and types of transport;
b) whether the animals have been held or transported in proximity to wild or domesticated animals of the same or other species and what specific diseases have been known to be carried by such animals.

D) SOURCE OF INDIVIDUALS. If the precise provenance of the confiscated animals is not known (they may be from several different sites of origin), or if there is any question of the source of animals, supplementation may lead to inadvertent pollution of distinct genetic races or subspecies. If particular local races or sub-species show specific adaptation to their local environments, mixing in individuals from other races or sub-species may be damaging to the local population. Where the origin and habitat and ecological requirements of the species are unknown, introducing an individual or individuals into the wrong habitat type may also doom them to death.

Given that any release incurs some risk, the following "precautionary principle" should be adopted: ***if there is no conservation value in releasing confiscated animals to the wild or no management programme exists within which such release can be undertaken according to conservation guidelines, the possibility of accidentally introducing a disease, or behavioural and genetic aberrations that are not already present into the environment, however unlikely, should rule out returning confiscated specimens to the wild as a placement option.***

Option 3 -- Euthanasia

Euthanasia -- the killing of animals carried out according to humane guidelines -- is a valid alternative to maintaining animals in captivity or returning them to the wild. Although it may appear counter-intuitive to employ euthanasia, it is, by definition, humane, and, thus can be wholly consistent with conservation and animal considerations. In many cases, it may be the most feasible option for conservation and humane, as well as economic, reasons. It is recognized that euthanasia is unlikely to be a popular option amongst confiscating authorities for disposition of confiscated animals. However, it cannot be overstressed that it may be the most responsible option. In many cases, authorities confiscating live animals will encounter the following situations:

a) In the course of trade or while held in captivity, the animals have contracted a chronic disease that is incurable and poses a risk to other animals, whether held in captivity or in the wild.

b) The actual provenance of the animals is unknown, and there is evidence to suggest that there may be genetic or other differences between them and presumed con-specifics in the wild, which could compromise the integrity of wild and captive populations, including those involved in breeding or conservation research activities.

c) There are insufficient resources to return the animals to the wild in accordance with biological (e.g., IUCN 1998) and animal welfare (e.g., International Academy of Welfare Sciences 1992) guidelines.

d) There are no feasible options for maintaining the animals in captivity.

In these instances, euthanasia may be the only responsible option and, thus, should be employed.

Euthanasia-- Benefits

a) With respect to the conservation of the species in question and of captive and wild populations of animals, euthanasia carries far fewer risks (e.g. disease, genetic pollution, biological invasion) than maintenance in captivity or return to the wild.

b) Euthanasia may be the best (and only) possible solution to an acute problem with confiscated animals. Many possibilities for maintenance in captivity may not guarantee the animals' welfare over the long term, and the survival prospects of animals returned to the wild are generally not high, as, depending on the circumstances, such animals often die of starvation, disease or predation.

c) Euthanasia acts to discourage the activities that gave rise to confiscation, as the animals in question are completely lost to the trade, with no chance of recovery by the traders involved. This removes any potential monetary gain from illegal trade. In addition, euthanasia may serve as a broader deterrent, in educating the public and other sectors about the serious and complex problems that can arise from trade in live wild animals.

d) The choice of euthanasia over maintenance in captivity or return to the wild offers an opportunity for confiscating authorities and other agencies to educate the public about more esoteric conservation problems, including those relating to invasive species and the potential negative consequences of releasing animals to the wild without adequate safeguards. Increased public awareness may generate additional ideas on placement of confiscated animals.

e) Euthanasia can be inexpensive as compared to other options. As such, it does not divert human and financial resources that could be allocated to other conservation or related activities, such as re-introduction or lifetime care of other animals, or the conservation of threatened species in the wild.

When animals are euthanized, or die in captivity, an effort should be made to make the best use of the dead specimens for scientific purposes, such as placing them in a reference collection in a university or research institute, which are very important for the study of biodiversity, or making them available for pathology or other research.

Euthansia- Risks

A) Just as there is potential positive educational value in employing euthanasia, there is a problem that it may give rise to negative perceptions of the confiscating authority for having taken that decision over other options. In such instances, there is a need to foresee such criticism and offer the rationale for the decision to euthanize.

B) There is a risk of losing unique behavioural, genetic and ecological material within an individual or group of individuals that represents variation within a species and may be of value for the conservation of the species.

Establishing the Necessary Frameworks

In order for prospective confiscating agencies to address the logistical, legal and other difficulties resulting from the seizure of wild animals, their eventual confiscation, and responsible disposition based on the above three options, there should be established an overall policy framework and specific procedures that *inter alia*:

- Identify the authority or authorities with responsibility for confiscation and placement of wild animals;
- Identify or provide the basis for establishing the facilities that will receive and, as necessary, quarantine, seized animals and hold them until final disposition is decided;
- Identify government or non-government agencies and experts that can assist in the identification, care, and screening of the seized or confiscated animals and assist in the process of deciding on appropriate disposition;
- Identify institutions, agencies, and private individuals and societies who can provide assistance to confiscating authorities in disposing of confiscated animals (including humane euthanasia) or can receive such animals;
- Elaborate on and provide for the implementation of the above guidelines in terms of specific legal and regulatory provisions and administrative procedures concerning transfer of ownership (including sale) of confiscated animals, short-term (e.g., upon seizure) and long-term (e.g., post-confiscation) care, levying of fees and other payments for care of confiscated animals, and other considerations that may be required to ensure that confiscated wild animals are disposed of responsibly in terms of both their welfare and the conservation.
- Produce and implement written policies on disposal of confiscated wildlife, taking steps to ensure that all enforcement personnel are provided the necessary resources to implement the policy.

Decision Tree Analysis

For decision trees dealing with "Return to the Wild" and "Captive Options," the confiscating party must first ask the question:

Question 1: Will "Return to the Wild" make a significant contribution to the conservation of the species? Is there a management programme that has sufficient resources to enable return according to IUCN Re-introduction Guidelines?

The most important consideration in deciding on placement of confiscated specimens is the conservation value of the specimen in question. Conservation interests are best served by ensuring the survival of as many individuals as possible; hence, the re-introduction of confiscated animals must improve the prospects for survival of the wild population. Re-introducing animals that have been held in captivity will always involve some level of risk to populations of the same or other species in the ecosystem, because there can never be absolute certainty that a confiscated animal is disease- and parasite-free. If the specimen is not of conservation value, the costs of re-introducing the animals to the wild may divert resources away from conservation programmes for other species or more effective conservation activities. In most instances, the benefits of return to the wild will be outweighed by the costs and risks of such an action. If returning animals to the wild is not of conservation value, captive options pose fewer risks and may offer more humane alternatives.

Q1 Answer: **Yes:** Investigate "Return to the Wild" Options.
NO: Investigate "Captive Options".

DECISION TREE ANALYSIS - CAPTIVITY

The decision to maintain confiscated animals in captivity involves a simpler set of considerations than that involving attempts to return confiscated animals to the wild.

Question 2: Have animals been subjected to comprehensive veterinary screening and quarantine?

Animals that may be transferred to captive facilities must have a clean bill of health because of the risk of introducing disease to captive populations. This should be established through quarantine and screening.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen, and proceed to Question 3

Question 3: Have animals been found to be disease-free by comprehensive veterinary screening and quarantine, or can they be treated for any infection discovered?

If, during quarantine, the animals are found to harbour diseases that cannot reasonably be cured, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, transfer to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: If chronic and incurable infection exists, first offer animals to research institutions. If impossible to place in such institutions, euthanize.

Question 4: Are there grounds for concern that certain options for transfer will stimulate further illegal or irregular trade or reduce the effectiveness of confiscation as a deterrent to such trade?

As much as possible, the confiscating authority should be satisfied that:
1) those involved in the illegal or irregular transaction that gave rise to confiscation cannot obtain the animals proposed for transfer;
2) the transfer does not compromise the objective of confiscation; and
3) the transfer will not increase illegal, irregular or otherwise undesired trade in the species.

What options can guarantee this will depend on the conservation status of the species in question, the nature of the trade in that species, and the circumstances of the specific incident that gave rise to confiscation. The payment of fees – to or by the confiscating authority – will complicate this assessment. Confiscating authorities must consider the various options for transfer in light of these concerns and weigh them against potential benefits that certain options might offer.
Answer: Yes: Proceed to Question 5a.
No: Proceed to Question 5b.

Question 5a: Is space available with a captive facility where the benefits of placement will outweigh concerns about the risks associated with transfer?

Question 5b: Is space available in a captive facility that offers particular benefits for the animals in question or the species?

There are a range of options for placement of confiscated animals in captivity, including public and private facilities, either commercial or non-commercial, specialist societies and individuals. Where several options for placement exist, it may be helpful to consider which offers the opportunity to maximize the conservation value of the animals, such as involvement in a conservation education or research programme or a captive-breeding programme. The conservation potential must be carefully weighed against the risk of stimulating trade that could exert further pressure on the wild population of the species.

Although placement with a commercial captive-breeding operation has the potential to reduce demand for wild-caught animals, this option should be carefully assessed: it may be difficult to monitor these facilities, and such programmes may, unintentionally or intentionally, stimulate trade in wild animals.. In many countries, there are active specialist societies or clubs of individuals with considerable expertise in the husbandry and breeding of individual species or groups of species. Such societies can assist in finding homes for confiscated animals with individuals who have expertise in the husbandry of those species

When a choice must be made between several options, the paramount consideration should be which option can:

1) offer the opportunity for the animals to participate in a programme that may benefit the conservation of the species;
2) provide the most consistent care; and
3) ensure the welfare of the animals.

In instances, where no facilities are available in the country in which animals are confiscated, transfer to a captive facility outside the country of confiscation may be possible. Whether to pursue this will depend on the conservation value of the species or the extent of interest in it. An important consideration in assessing this option is the cost involved and the extent to which these resources may be more effectively allocated to other conservation efforts.

The confiscating authorities should conclude an agreement to transfer confiscated animals to captive facilities. This agreement should set forth the terms and conditions of the transfer, including:

a) restrictions on any use (e.g., exhibition, education, captive breeding), commercial or non-commercial, that the animals may be put to;
b) a commitment to ensure life-time care or, in the event that this becomes impossible, transfer to another facility that can ensure life-time care, or to euthanize the animals; and
c) conditions regarding subsequent transfer of ownership, including sale, of the animals or their offspring.

Q5 Answer: Yes: Execute agreement and sell.
No: Proceed to Question 6.

Question 6: Are institutions interested in animals for research under humane conditions?

Many research institutions maintain collections of exotic animals for research conducted under humane conditions. If these animals are kept in conditions that ensure their welfare, transfer to such institutions may provide an acceptable alternative to other options, such as transfer to another captive facility or euthanasia. As in the preceding instances, such transfer should be subject to terms and conditions agreed with the confiscating authority; in addition to those already suggested, it may be advisable to include terms that stipulate the types of research the confiscating authority considers permissible. If no placement is possible, the animals should be euthanized.

Q6 Answer: Yes: Execute Agreement and Transfer.
No: Euthanize.

DECISION TREE ANALYSIS -- RETURN TO THE WILD

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Because of the risk of introducing disease to wild populations, confiscated animals that may be released must have a clean bill of health. The animals must be placed in quarantine to determine if they are disease-free before being considered for released.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen, and proceed to Question 3.

Question 3: Have animals been found to be disease-free by comprehensive veterinary screening and quarantine, or can they be treated for any infection discovered?

If, during quarantine, the confiscated animals are found to harbour diseases that cannot reasonably be cured, unless any institutions are interested in the animals for research under humane conditions, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or ethanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: If chronic and incurable infection exists, first offer animals to research institutions. If impossible to place in such institutions, euthanize.

Question 4: Can the country of origin and site of capture be confirmed?

The geographical location from which confiscated animals have been removed from the wild must be determined if these individuals are to be used to re-inforce existing wild populations. As a general rule, animals should only be returned to the population from which they were taken, or from populations that are known to have natural exchange of individuals with this population.

If provenance of the animals is not known, release for reinforcement may lead to inadvertent hybridisation of distinct genetic races or sub-species. Related species of animals that may live in sympatry in the wild and never hybridise have been known to hybridise when held in captivity in multi-species groups. This type of generalisation of species recognition under abnormal conditions can result in behavioural problems, which can compromise the success of any future release and also pose a threat to wild populations by artificially destroying reproductive isolation that is behaviourally mediated.

Q4 Answer: Yes: Proceed to Question 5.
No: Pursue 'Captive Options'.

Question 5: Do the animals exhibit behavioural abnormalities that might make them unsuitable for return to the wild?

Behavioural abnormalities as a result of captivity can render animals unsuitable for release into the wild. A wide variety of behavioural traits and specific behavioural skills are necessary for survival, in the short-term for the individual, and in the long-term for the population. Skills for hunting, avoiding predators, food selectivity, etc. are necessary to ensure survival.

Q5 Answer: Yes: Pursue 'Captive Options'.
No: Proceed to Question 6.

Question 6: Can the animals be returned expeditiously to their site of origin (specific location), and will benefits to conservation of the species outweigh any risks of such action?

Return of the animals to the wild through reinforcement of the wild population should follow the IUCN Re-introduction Guidelines (see Annex 4) and will only be an option under certain conditions, including:

a) appropriate habitat for such an operation still exists in the specific location that the individual was removed from; and
b) sufficient funds are available, or can be made available.

Q6 Answer: Yes: Re-inforce at origin (specific location) following IUCN Guidelines.
No: Proceed to Question 7.

Question 7: For the species in question, does a generally recognized programme exist the aim of which is conservation of the species and eventual return to the wild of confiscated individuals and/or their progeny? *Contact IUCN/SSC, IIUDZG, Studbook Keeper, or Breeding Programme Coordinator (See Annex 3).*

In the case of species for which active captive breeding and/or re-introduction programmes exist, and for which further breeding stock/founders are required, confiscated animals should be transferred to such programmes after consultation with the appropriate scientific authorities. If the species in question is part of a captive breeding programme, but the taxon (sub-species or race) is not part of this programme, other methods of disposition must be considered. Particular attention should be paid to genetic screening to avoid jeopardizing captive breeding programmes through inadvertent hybridisation.

Q7 Answer: Yes: Execute agreement and transfer to existing programme.
No: Proceed to Question 8.

Question 8: Is there a need, and is it feasible to establish a new re-introduction programme *following IUCN Guidelines*?

In cases where individuals cannot be transferred to existing re-introduction programmes, re-introduction following IUCN Guidelines, may be possible, providing:

a) appropriate habitat exists for such an operation;
b) sufficient funds are available, or can be made available, to support a programme over the many years that (re)introduction will require; and

c) sufficient numbers of animals are available so that re-introduction efforts are potentially viable.

In the majority of cases, at least one, if not all, of these requirements will fail to be met. In this instance, either conservation introductions outside the historical range of the species or other options for disposition of the animals must be considered.

If a particular species is confiscated with some frequency, consideration should be made as to whether to establish a re-introduction, reinforcement, or introduction programme for that species. Animals should not be held by the confiscating authority indefinitely while such programmes are planned, but should be transferred to a holding facility after consultation with the organization which is establishing the new programme.

Q8 Answer: Yes: Execute agreement and transfer to holding facility or new programme.
No: Pursue 'Captive Options'.

Relevant Documents

CITES. 1997. Resolution Conf. 10.7: Disposal of Confiscated Live Specimens of Species Included in the Appendices. Adopted at the Tenth Meeting of the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Harare, 1997).
(Available from CITES Secretariat or from http://www.wcmc.org.uk/CITES/)

IUCN. 1987. *The IUCN position statement on translocation of living organisms: introductions, re-introductions and restocking*. IUCN, Gland, Switzerland.
(Available from IUCN/SSC or from http://iucn.org/themes/ssc/PUBS/POLICY/INDEX.HTM)

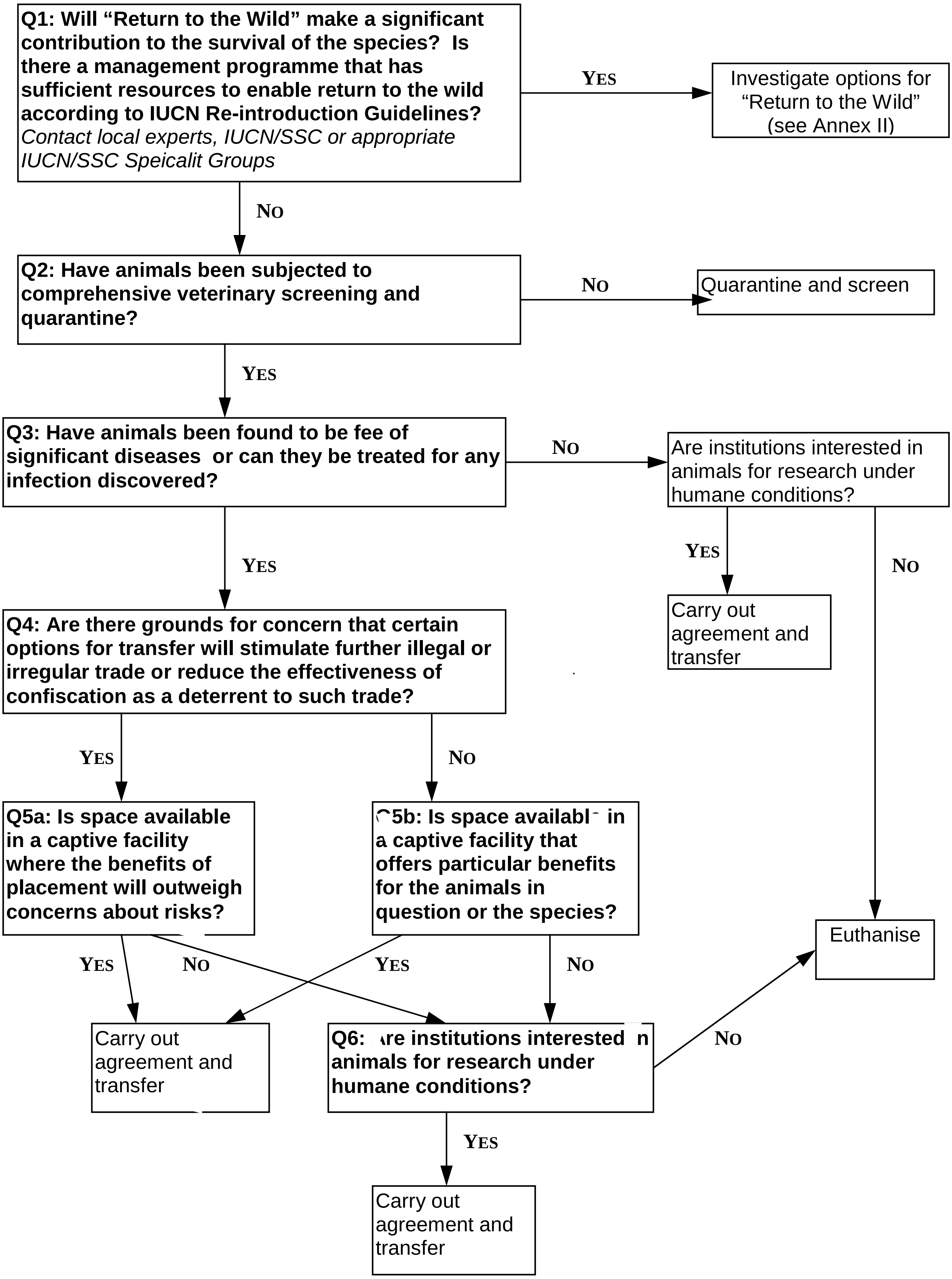
IUCN. 1998. *IUCN Guidelines for Re-introductions.* Prepared by the IUCN/SSC Reintroductions Specialist Group. IUCN, Gland Switzerland and Cambridge, UK.
(Available from IUCN Publications Services Unit or from http://iucn.org./themes/ssc/PUBS/POLICY/INDEX.HTM)

IUCN. In prep. IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion.
Prepared by the IUCN/SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland.

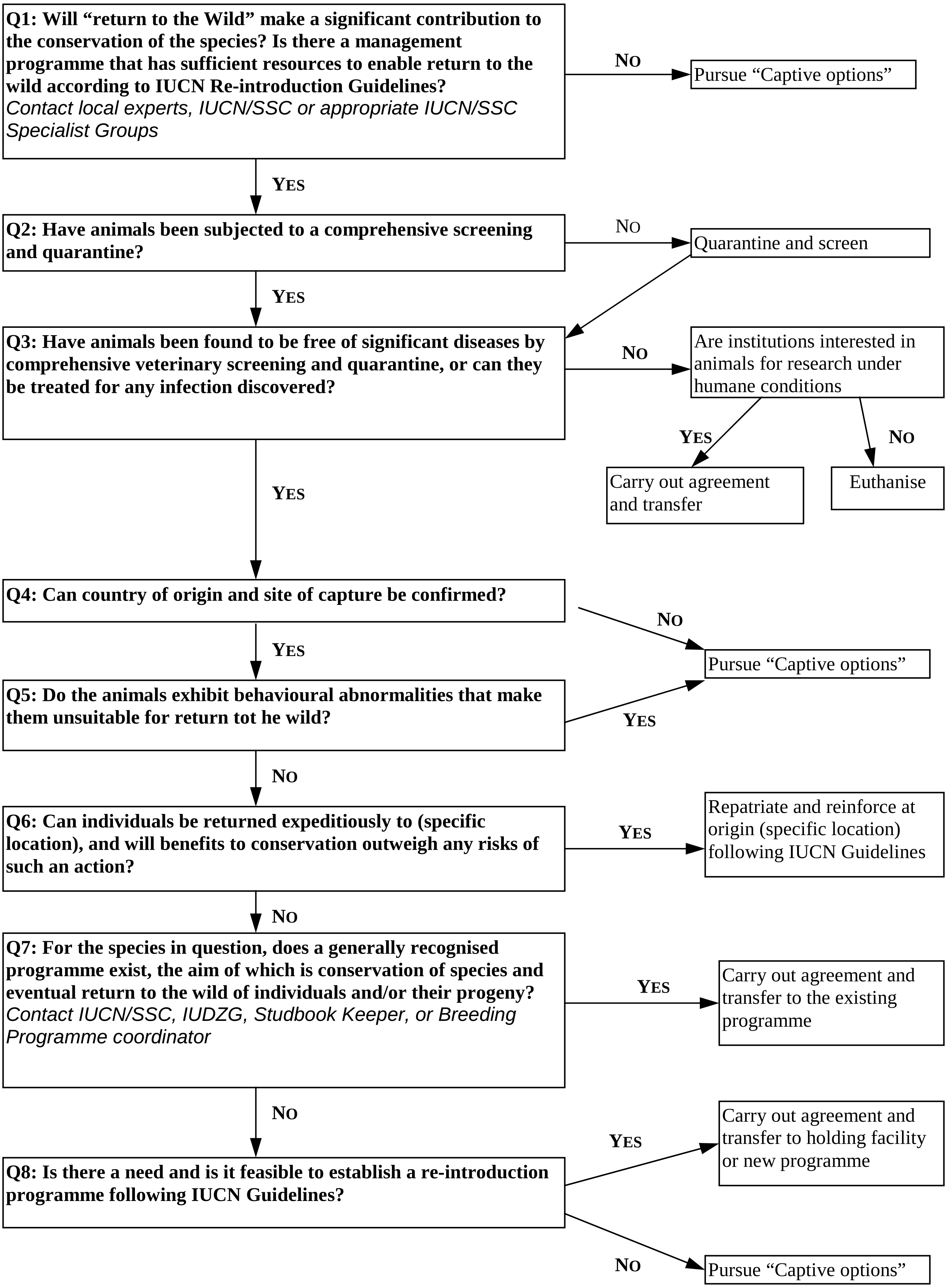
IUDZG/CBSG. 1993. *The World Zoo Conservation Strategy. The Role of Zoos and Aquaria of the World in Global Conservation*. IUDZG-the World Zoo Organization.

Annexes

Annex 1- Decision Tree for Captive Options



Annex 2 - Decision Tree for Return to the Wild



Annex 3 - Key Contacts

IUCN Species Survival Commission

Contact: Species Survival Programme,
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Website: *http://www.iucn.org/themes/ssc/index.htm*

Taxonomic Specialist Groups

Contact details for individual taxonomic specialist groups of SSC are available through IUCN at the contact details and IUCN website address provided above.

Disciplinary Specialist Groups

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Website: *www.cites.org*

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IUCN

The World Conservation Union

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IUCN Guidelines for Re-introductions

Prepared by the IUCN/SSC Re-introduction Specialist Group

IUCN
The World Conservation Union

Species Survival Commission

African Wildlife Foundation

RSG

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AWF is an international non-governmental organisation working for conservation and development in Africa. AWF works in partnership with national governments, non-governmental organizations, research and training institutions, community groups, associations and donor agencies, in order to promote the sound protection and management of natural resources in Africa.

AWF's current programme focuses on four approaches to conservation namely Community Conservation; Training and Institutional Development; Conservation, Economics and Commerce; and Species and Ecosystems.

The Species and Ecosystems Programme seeks to enhance the conservation of species and ecosystems of conservation significance in Africa, and minimize the threats to in-situ conservation of Africa's biological diversity posed by inadequate support for resource management. AWF supports the work of the RSG as part of its Species and Ecosystems Programme, recognizing that the extreme vulnerability of small populations is a global conservation problem, and that lessons learned can be usefully shared between Africa and other continents.

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The OES has the principal responsibility for formulating and implementing U.S. policies for oceans, environmental, scientific, and technological aspects of U.S. relations with other governmental and multilateral institutions. The Bureau's activities cover a broad range of foreign policy issues relating to environment, pollution, tropical forests, biological diversity, wildlife, oceans policy, fisheries, global climate change, atmospheric ozone-depletion, space, and advanced technologies.

These Guidelines are available in booklet form in the following language versions:
Arabic/English, Chinese/English, French/English, Russian/English, Spanish/English, and English only, from the IUCN Publications Service Unit (see address on inside front cover).

They are also available on the Web in English, French and Spanish, at:
http://iucn.org/themes/ssc/pubs/policy/index~1.htm

IUCN/SSC Guidelines for Re-Introductions

Prepared by the SSC Re-introduction Specialist Group

Approved by the 41st Meeting of the IUCN Council, Gland Switzerland, May 1995

INTRODUCTION

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission **(1)**, in response to the increasing occurrence of re-introduction projects worldwide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although IUCN developed a *Position Statement on the Translocation of Living Organisms* in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocations of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. It should be noted that re-introduction is always a very lengthy, complex and expensive process.

Re-introductions or translocations of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue and beyond the scope of these guidelines. These include fishing and hunting activities.

This document has been written to encompass the full range of plant and animal taxa and is therefore general. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

CONTEXT

The increasing number of re-introductions and translocations led to the establishment of the IUCN/SSC Species Survival Commission's Re-introduction Specialist Group. A priority of the Group has been to update IUCN's 1987 Position Statement on the Translocation of Living Organisms, in consultation with IUCN's other commissions.

It is important that the Guidelines are implemented in the context of IUCN's broader policies pertaining to biodiversity conservation and sustainable management of natural resources. The philosophy for environmental conservation and management of IUCN and other conservation bodies is stated in key documents such as "Caring for the Earth" and "Global Biodiversity Strategy" which cover the broad themes of the need for approaches with community involvement and participation in sustainable natural resource conservation, an overall enhanced quality of human life and the need to conserve and, where necessary, restore ecosystems. With regards to the latter, the re-introduction of a species is one specific instance of restoration where, in general, only this species is missing. Full restoration of an array of plant and animal species has rarely been tried to date.

Restoration of single species of plants and animals is becoming more frequent around the world. Some succeed, many fail. As this form of ecological management is increasingly common, it is a priority for the Species Survival Commission's Re-introduction Specialist Group to develop guidelines so that re-introductions are both justifiable and likely to succeed, and that the conservation world can learn from each initiative, whether successful or not. It is hoped that these Guidelines, based on extensive review of case - histories and wide consultation across a range of disciplines will introduce more rigour into the concepts, design, feasibility and implementation of re-introductions despite the wide diversity of species and conditions involved.

Thus the priority has been to develop guidelines that are of direct, practical assistance to those planning, approving or carrying out re-introductions. The primary audience of these guidelines is, therefore, the practitioners (usually managers or scientists), rather than decision makers in governments. Guidelines directed towards the latter group would inevitably have to go into greater depth on legal and policy issues.

1. DEFINITION OF TERMS

"Re-introduction": an attempt to establish a species **(2)** in an area which was once part of its historical range, but from which it has been extirpated or become extinct **(3)** ("Re-establishment" is a synonym, but implies that the re-introduction has been successful).

"Translocation": deliberate and mediated movement of wild individuals or populations from one part of their range to another.

"Re-inforcement/Supplementation": addition of individuals to an existing population of conspecifics.

"Conservation/Benign Introductions": an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species' historic range.

2. AIMS AND OBJECTIVES OF RE-INTRODUCTION

a. Aims:

The principle aim of any re-introduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race, which has become globally or locally extinct, or extirpated, in the wild. It should be re-introduced within the species' former natural habitat and range and should require minimal long-term management.

b. Objectives:

The objectives of a re-introduction may include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain and/or restore natural biodiversity; to provide long-term economic benefits to the local and/or nataional economy; to promote conservation awareness; or a combination of these.

3. MULTIDISCIPLINARY APPROACH

A re-introduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. As well as government personnel, they may include persons from governmental natural resource management agencies; non-governmental organisations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

4. PRE-PROJECT ACTIVITIES

4a. BIOLOGICAL

(i) Feasibility study and background research

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They should preferably be of the same subspecies or race as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt as to individuals' taxonomic status. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.
- Detailed studies should be made of the status and biology of wild populations(if they exist) to determine the species' critical needs. For animals, this would include descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For migratory species, studies should include the potential migratory areas. For plants, it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.
- The species, if any, that has filled the void created by the loss of the species concerned, should be determined; an understanding of the effect the re-introduced species will have on the ecosystem is important for ascertaining the success of the re-introduced population.
- The build-up of the released population should be modelled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.
- A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

- Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

(iii) Choice of release site and type

- Site should be within the historic range of the species. For an initial re-inforcement there should be few remnant wild individuals. For a re-introduction, there should be no remnant population to prevent disease spread, social disruption and introduction of alien genes. In some circumstances, a re-introduction or re-inforcement may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range.

- A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist and only when a significant contribution to the conservation of the species will result.
- The re-introduction area should have assured, long-term protection (whether formal or otherwise).

(iv) Evaluation of re-introduction site

- Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. Likewise, a change in the legal/ political or cultural environment since species extirpation needs to be ascertained and evaluated as a possible constraint. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.
- Identification and elimination, or reduction to a sufficient level, of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal. Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the re-introduction is carried out.

(v) Availability of suitable release stock

- It is desirable that source animals come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (morphology, physiology, behaviour, habitat preference) to the original sub-population.
- Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.
- Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.
- If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.
- Re-introductions should not be carried out merely because captive stocks exist, nor solely as a means of disposing of surplus stock.
- Prospective release stock, including stock that is a gift between governments, must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for non-endemic or contagious pathogens with a potential impact on population levels, must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.
- Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.
- Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

(vi) Release of captive stock

- Most species of mammal and birds rely heavily on individual experience and learning as juveniles for their survival; they should be given the opportunity to acquire the necessary information to enable survival in the wild, through training in their captive environment; a captive bred individual's probability of survival should approximate that of a wild counterpart.
- Care should be taken to ensure that potentially dangerous captive bred animals (such as large carnivores or primates) are not so confident in the presence of humans that they might be a danger to local inhabitants and/or their livestock.

4b. SOCIO-ECONOMIC AND LEGAL REQUIREMENTS

- Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.
- Socio-economic studies should be made to assess impacts, costs and benefits of the re-introduction programme to local human populations.
- A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss or alteration of habitat). The programme should be fully understood, accepted and supported by local communities.
- Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimise these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.
- The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing provincial, national and international legislation and regulations, and provision of new measures and required permits as necessary.
- Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state or when a re-introduced population can expand into other states, provinces or territories.
- If the species poses potential risk to life or property, these risks should be minimised and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered. In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

5. PLANNING, PREPARATION AND RELEASE STAGES

- Approval of relevant government agencies and land owners, and coordination with national and international conservation organizations.
- Construction of a multidisciplinary team with access to expert technical advice for all phases of the programme.
- Identification of short- and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.
- Securing adequate funding for all programme phases.
- Design of pre- and post- release monitoring programme so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data. Monitoring the health of individuals, as well as the survival, is important; intervention may be necessary if the situation proves unforseeably favourable.

- Appropriate health and genetic screening of release stock, including stock that is a gift between governments. Health screening of closely related species in the re-introduction area.
- If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.
- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.
- Appropriate veterinary or horticultural measures as required to ensure health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.
- Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.
- Determination of release strategy (acclimatization of release stock to release area; behavioural training - including hunting and feeding; group composition, number, release patterns and techniques; timing).
- Establishment of policies on interventions (see below).
- Development of conservation education for long-term support; professional training of individuals involved in the long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.
- The welfare of animals for release is of paramount concern through all these stages.

6. POST-RELEASE ACTIVITIES

- Post release monitoring is required of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.
- Demographic, ecological and behavioural studies of released stock must be undertaken.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision, rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

Footnotes:

(1): Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN.

(2): The taxonomic unit referred to throughout the document is species; it may be a lower taxonomic unit (e.g. subspecies or race) as long as it can be unambiguously defined.

(3): A taxon is extinct when there is no reasonable doubt that the last individual has died

The IUCN/SSC Re-introduction Specialist Group (RSG) is a disciplinary group (as opposed to most SSC Specialist Groups which deal with single taxonomic groups), covering a wide range of plant and animal species. The RSG has an extensive international network, a re-introduction projects database and re-introduction library. The RSG publishes a bi-annual newsletter RE-INTRODUCTION NEWS.

If you are a re-introduction practitioner or interested in re-introductions please contact:

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The World Conservation Union

Information Paper

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(Nairobi, Kenya 15-26 May 2000)

IUCN Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species

As approved by 51st Meeting of Council, February 2000

These guidelines address four substantive concerns of the biological alien invasion problem. These are:

- *improving understanding and awareness;*
- *strengthening the management response (including prevention, eradication and control);*
- *providing appropriate legal and institutional mechanisms;*
- *enhancing knowledge and research efforts.*

These guidelines were initiated at IUCN's 19th General Assembly in 1994 to update a previous IUCN position statement on "Translocation of living organisms" (September 1987). A first draft was presented at the 1st IUCN World Conservation Congress (WCC) in Montreal (1996). Extensive comments were received following the publication of "Conserving Vitality and Diversity" (proceedings of the WCC workshop on alien invasive species), and the draft Guidelines were rewritten in line with these comments in 1998. This revision was circulated to legal and invasive species experts in early 1999, and in March 1999 to all IUCN members in the three official languages. Additional comments were then integrated. The Guidelines were approved by the 51st Meeting of IUCN Council, February 2000.

Customs, quarantine and other import/export practices, developed in an earlier time to guard against human and economic diseases and pests, are often inadequate safeguards against species that threaten native biodiversity. The aim of the IUCN Guidelines is to help address this gap in a timely fashion and to move away from the older, more narrow premises that primarily related to agriculture and human health. This is why the IUCN Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species are concerned with preventing loss of native biological diversity[1] caused by biological invasions of alien invasive species, and do not address the economic (agricultural, forestry, aquaculture etc.) or health impacts caused by alien invasive species. Economic and health impacts caused by alien invasive species are to various degrees covered by conventions and rules including the International Plant Protection

[1] IUCN is also contributing to broader invasive species guidelines (i.e. covering more issues than just the conservation of native species) through GISP.

Convention (IPPC), the Office International des Epizooties (OIE), and the World Health Organization. By adding the IUCN Guidelines, a complimentarity is achieved so that implementation of article 8(h), and the recommendations from SBSTTA 4 and 5 can now be approached more holistically.

The IUCN Guidelines are firmly based on the precautionary approach, and on what is required to prevent biodiversity loss (native) caused by alien invasive species. They are meant to aim high towards an ideal solution, and it is not expected that all recommended actions would be put into practice in the short term.

The aim is to:

- *assist managers, policy or decision-makers, at all levels (local, national, regional) to give effect to Article 8(h) of the Convention on Biological Diversity;*
- *contribute to the development of strategies, regulations and practical measures by international, regional, national and local bodies, including (but not limited to) CBD, SPREP (the South Pacific Regional Environment Programme) , GISP (Global Invasive Species Programme, of which IUCN is one of the partners), CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), WTO (World Trade Organisation);*
- *play a role in awareness-raising of all stakeholders involved in the invasives issue.*

IUCN would be pleased to provide copies of these Guidelines.

Currently only the English version is available - translations will be undertaken in the near future (pending availability of funding).

1. BACKGROUND[2]

Biological diversity faces many threats throughout the world. One of the major threats to native biological diversity is now acknowledged by scientists and governments to be biological invasions caused by alien invasive species. The impacts of alien invasive species are immense, insidious, and usually irreversible. They may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats.

For millennia, the natural barriers of oceans, mountains, rivers and deserts provided the isolation essential for unique species and ecosystems to evolve. In just a few hundred years these barriers have been rendered ineffective by major global forces that combined to help alien species travel vast distances to new habitats and become alien invasive species. The globalisation and growth in the volume of trade and tourism, coupled with the emphasis on free trade, provide more opportunities than ever before for species to be spread accidentally or deliberately. Customs and quarantine practices, developed in an earlier time to guard against human and economic diseases and pests, are often inadequate safeguards against species that threaten native biodiversity. Thus the inadvertent ending of millions of years of biological isolation has created major ongoing problems that affect developed and developing countries.

[2] Definition of Terms in section 3

The scope and cost of biological alien invasions is global and enormous, in both ecological and economic terms. Alien invasive species are found in all taxonomic groups: they include introduced viruses, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals. They have invaded and affected native biota in virtually every ecosystem type on Earth. Hundreds of extinctions have been caused by alien invasives. The ecological cost is the irretrievable loss of native species and ecosystems.

In addition, the direct economic costs of alien invasive species run into many billions of dollars annually. Arable weeds reduce crop yields and increase costs; weeds degrade catchment areas and freshwater ecosystems; tourists and homeowners unwittingly introduce alien plants into wilderness and natural areas; pests and pathogens of crops, livestock and forests reduce yields and increase control costs. The discharge of ballast water together with hull fouling has led to unplanned and unwanted introductions of harmful aquatic organisms, including diseases, bacteria and viruses, in marine and freshwater systems. Ballast water is now regarded as the most important vector for trans-oceanic and inter-oceanic movements of shallow-water coastal organisms. Factors like environmental pollution and habitat destruction can provide conditions that favour alien invasive species.

The degradation of natural habitats, ecosystems and agricultural lands (e.g. loss of cover and soil, pollution of land and waterways) that has occurred throughout the world has made it easier for alien species to establish and become invasive. Many alien invasives are “colonising” species that benefit from the reduced competition that follows habitat degradation. Global climate change is also a significant factor assisting the spread and establishment of alien invasive species. For example, increased temperatures may enable alien, disease-carrying mosquitoes to extend their range.

Sometimes the information that could alert management agencies to the potential dangers of new introductions is not known. Frequently, however, useful information is not widely shared or available in an appropriate format for many countries to take prompt action, assuming they have the resources, necessary infrastructure, commitment and trained staff to do so.

Few countries have developed the comprehensive legal and institutional systems that are capable of responding effectively to these new flows of goods, visitors and ‘hitchhiker’ species. Many citizens, key sector groups and governments have a poor appreciation of the magnitude and economic costs of the problem. As a consequence, responses are too often piecemeal, late and ineffective. It is in this context that IUCN has identified the problem of alien invasive species as one of its major initiatives at the global level.

While all continental areas have suffered from biological alien invasions, and lost biological diversity as a result, the problem is especially acute on islands in general, and for small island countries in particular. Problems also arise in other isolated habitats and ecosystems, such as in Antarctica. The physical isolation of islands over millions of years has favored the evolution of unique species and ecosystems. As a consequence, islands and other isolated areas (e.g. mountains and lakes) usually have a high proportion of endemic species (those found nowhere else) and are centres of significant biological diversity. The evolutionary processes associated with isolation have also meant island species are especially vulnerable to competitors, predators, pathogens and parasites from other areas. It is important to turn this isolation of islands into an advantage by improving the capacity of governments to prevent the arrival of alien invasive species with better knowledge, improved laws and greater management capacity, backed by quarantine and customs systems that are capable of identifying and intercepting alien invasive species.

2. GOALS AND OBJECTIVES

The goal of these guidelines is to prevent further losses of biological diversity due to the deleterious effects of alien invasive species. The intention is to assist governments and management agencies to give effect to Article 8 (h) of the Convention on Biological Diversity, which states that:

"Each Contracting Party shall, as far as possible and as appropriate:

...(h) *Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species*."

These guidelines draw on and incorporate relevant parts of the 1987 IUCN Position Statement on Translocation of Living Organisms although they are more comprehensive in scope than the 1987 Translocation Statement. The relationship to another relevant guideline, the IUCN Guidelines for Re-introductions, is elaborated in Section 7.

These guidelines are concerned with preventing loss of biological diversity caused by biological invasions of alien invasive species. They do not address the issue of genetically modified organisms, although many of the issues and principles stated here could apply. Neither do these guidelines address the economic (agricultural, forestry, aquaculture), human health and cultural impacts caused by biological invasions of alien invasive species.

These guidelines address four substantive concerns of the biological alien invasion problem that can be identified from this background context. These are:

- improving understanding and awareness;
- strengthening the management response;
- providing appropriate legal and institutional mechanisms;
- enhancing knowledge and research efforts.

While addressing all four concerns is important, these particular guidelines focus most strongly on aspects of strengthening the management response. This focus reflects the urgent need to spread information on management that can quickly be put into place to prevent alien invasions and eradicate or control established alien invasives. Addressing the other concerns, particularly the legal and research ones, may require longer-term strategies to achieve the necessary changes.

These guidelines have the following seven objectives:

1. To increase awareness of alien invasive species as a major issue affecting native biodiversity in developed and developing counties and in all regions of the world.

2. To encourage prevention of alien invasive species introductions as a priority issue requiring national and international action.

3. To minimise the number of unintentional introductions and to prevent unauthorised introductions of alien species.

4. To ensure that intentional introductions, including those for biological control purposes, are properly evaluated in advance, with full regard to potential impacts on biodiversity.

5. To encourage the development and implementation of eradication and control campaigns and programmes for alien invasive species, and to increase the effectiveness of those campaigns and programmes.

6. To encourage the development of a comprehensive framework for national legislation and international cooperation to regulate the introduction of alien species as well as the eradication and control of alien invasive species.

7. To encourage necessary research and the development and sharing of an adequate knowledge base to address the problem of alien invasive species worldwide

3. DEFINITION OF TERMS[3]

"**Alien invasive species**" means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

"**Alien species**" (non-native, non-indigenous, foreign, exotic) means a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce.

"**Biological diversity**" (biodiversity) means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

"**Biosecurity threats**" means those matters or activities which, individually or collectively, may constitute a biological risk to the ecological welfare or to the well-being of humans, animals or plants of a country.

"**Government**" includes regional co-operating groupings of governments for matters falling within their areas of competence.

[3] At the time of adoption of these Guidelines by IUCN, standard terminology relating to alien invasive species has not been developed in the CBD context. Definitions used in this document were developed by IUCN in the specific context of native biodiversity loss caused by alien invasive species.

"**Intentional introduction**" means an introduction made deliberately by humans, involving the purposeful movement of a species outside of its natural range and dispersal potential. (Such introductions may be authorised or unauthorised.)

"**Introduction**" means the movement, by human agency, of a species, subspecies, or lower taxon (including any part, gametes or propagule that might survive and subsequently reproduce) outside its natural range (past or present). This movement can be either within a country or between countries.

"**Native species**"(indigenous) means a species, subspecies, or lower taxon, occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans.)

"**Natural ecosystem**" means an ecosystem not perceptibly altered by humans.

"**Re-introduction**" means an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct. (From IUCN Guidelines for Re-Introductions)

"**Semi-natural ecosystem**" means an ecosystem which has been altered by human actions, but which retains significant native elements.

"**Unintentional introduction**" means an unintended introduction made as a result of a species utilising humans or human delivery systems as vectors for dispersal outside its natural range.

4. UNDERSTANDING AND AWARENESS

4.1 Guiding Principles

❖ Understanding and awareness, based on information and knowledge, are essential for establishing alien invasive species as a priority issue which can and must be addressed.

❖ Better information and education, and improved public awareness of alien invasive issues by all sectors of society, is fundamental to preventing or reducing the risk of unintentional or unauthorised introductions, and to establishing evaluation and authorisation procedures for proposed intentional introductions.

❖ Control and eradication of alien invasive species is more likely to be successful if supported by informed and cooperating local communities, appropriate sectors and groups.

❖ Information and research findings which are well communicated are vital prerequisites to education, understanding and awareness. (See Section 8.)

4.2 Recommended Actions

1. Identify the specific interests and roles of relevant sectors and communities with respect to alien invasive species issues and target them with appropriate information and recommended actions.

Specific communication strategies for each target group will be required to help reduce the risks posed by alien invasive species. The general public is an important target group to be considered.

2. Make easily accessible, current and accurate information widely available as a key component of awareness raising. Target different audiences with information in electronic form, manuals, databases, scientific journals and popular publications. (See also Section 8.)

3. Target importers and exporters of goods, as well as of living organisms as key target groups for information/education efforts leading to better awareness and understanding of the issues, and their role in prevention and possible solutions.

4. Encourage the private sector to develop and follow best practice guidelines and monitor adherence to guidelines. (Refer 5.2 and 5.3.)

5. As an important priority, provide information and recommended actions to travellers, both within country and between countries, preferably prior to the start of journeys. Raising awareness of how much human travel contributes to alien invasive problems can improve behaviour and be cost-effective.

6. Encourage operators in eco-tourism businesses to raise awareness on the problems caused by alien invasive species. Work with such operators to develop industry guidelines to prevent the unintentional transport or unauthorised introduction of alien plants (especially seeds) and animals into ecologically vulnerable island habitats and ecosystems (e.g. lakes, mountain areas, nature reserves, wilderness areas, isolated forests and inshore marine ecosystems).

7. Train staff for quarantine, border control, or other relevant facilities to be aware of the larger context and threats to biological diversity, in addition to practical training for aspects like identification and regulation. (See Section 5.2.)

8. Build communication strategies into the planning phase of all prevention, eradication and control programmes. By ensuring that effective consultation takes place with local communities and all affected parties, most potential misunderstandings and disagreements can be resolved or accommodated in advance.

9. Include alien invasive species issues, and actions that can be taken to address them, in appropriate places in educational programmes and schools.

10. Ensure that national legislation applicable to introductions of alien species, both intentional and unintentional, is known and understood, not only by the citizens and institutions of the country concerned, but also by foreigners importing goods and services as well as by tourists.

5. PREVENTION AND INTRODUCTIONS

5.1 Guiding Principles

- ❖ Preventing the introduction of alien invasive species is the cheapest, most effective and most preferred option and warrants the highest priority.

- Rapid action to prevent the introduction of potential alien invasives is appropriate, even if there is scientific uncertainty about the long-term outcomes of the potential alien invasion.

- Vulnerable ecosystems should be accorded the highest priority for action, especially for prevention initiatives, and particularly when significant biodiversity values are at risk. Vulnerable ecosystems include islands and isolated ecosystems such as lakes and other freshwater ecosystems, cloud forests, coastal habitats and mountain ecosystems.

- Since the impacts on biological diversity of many alien species are unpredictable, any intentional introductions and efforts to identify and prevent unintentional introductions should be based on the precautionary principle.

- In the context of alien species, unless there is a reasonable likelihood that an introduction will be harmless, it should be treated as likely to be harmful.

- Alien invasives act as “biological pollution” agents that can negatively affect development and quality of life. Hence, part of the regulatory response to the introduction of alien invasive species should be the principle that “the polluter pays” where “pollution” represents the damage to native biological diversity.

- Biosecurity threats justify the development and implementation of comprehensive legal and institutional frameworks.

- The risk of unintentional introductions should be minimised.

- Intentional introductions should only take place with authorisation from the relevant agency or authority. Authorisation should require comprehensive evaluations based on biodiversity considerations (ecosystem, species, genome). Unauthorised introductions should be prevented.

- The intentional introduction of an alien species should only be permitted if the positive effects on the environment outweigh the actual and potential adverse effects. This principle is particularly important when applied to isolated habitats and ecosystems, such as islands, fresh water systems or centres of endemism.

- The intentional introduction of an alien species should not be permitted if experience elsewhere indicates that the probable result will be the extinction or significant loss of biological diversity.

- The intentional introduction of an alien species should only be considered if no native species is considered suitable for the purposes for which the introduction is being made.

5.2 Unintentional Introductions – Recommended Actions

Unfortunately, it can be very difficult to control unintentional introductions that occur through a wide variety of ways and means. They include the most difficult types of movement to identify, control and prevent. By their very nature the most practical means of minimising unintentional introductions is by identifying, regulating and monitoring the major pathways. While pathways vary between countries and regions, the best known are international and national trade and tourism routes, through which the unintentional movement and establishment of many alien species occurs.

Recommended actions to reduce the likelihood of unintentional introductions are:

1. Identify and manage pathways leading to unintentional introductions. Important pathways of unintentional introductions include: national and international trade, tourism, shipping, ballast water, fisheries, agriculture, construction projects, ground and air transport, forestry, horticulture, landscaping, pet trade and aquaculture.

2. Contracting parties to the Convention on Biological Diversity, and other affected countries, should work with the wide range of relevant international trade authorities and industry associations, with the goal of significantly reducing the risk that trade will facilitate the introduction and spread of alien invasive species.

3. Develop collaborative industry guidelines and codes of conduct, which minimise or eliminate unintentional introductions.

4. Examine regional trade organisations and agreements to minimise or eliminate unintentional introductions that are caused by their actions.

5. Explore measures such as: elimination of economic incentives that assist the introduction of alien invasive species; legislative sanctions for introductions of alien species unless no fault can be proved; internationally available information on alien invasive species, by country or region, for use in border and quarantine control, as well as for prevention, eradication and control activities. (See also Section 8.)

6. Implement the appropriate initiatives to reduce the problems of alien invasives arising from ballast water discharges and hull fouling. These include: better ballast water management practices; improved ship design; development of national ballast water programmes; research, sampling and monitoring regimes; information to port authorities and ships' crews on ballast water hazards. Make available existing national guidelines and legislation on ballast water (for example Australia, New Zealand, USA**).** At the national, regional and international level, disseminate international guidelines and recommendations, such as the International Maritime Organisation's guidelines on ballast water and sediment discharges. (See also Section 9.2.2.)

7. Put in place quarantine and border control regulations and facilities and train staff to intercept the unintentional introduction of alien species. Quarantine and border control regulations should not be premised only on narrow economic grounds that primarily relate to agriculture and human health, but, in addition, on the unique biosecurity threats each country is exposed to. Improved performance at intercepting unintentional introductions that arrive via major pathways may require an expansion of the responsibilities and resourcing of border control and quarantine services. (Also see 9.2)

8. Address the risks of unintentional introductions associated with certain types of goods or packaging through border control legislation and procedures.

9. Put in place appropriate fines, penalties or other sanctions to apply to those responsible for unintentional introductions through negligence and bad practice.

10. Ensure compliance by companies dealing with transport or movement of living organisms with the biosecurity regimes established by governments in the exporting and importing countries. Provide for their activities to be subjected to appropriate levels of monitoring and control.

11. For island countries with high risks and high vulnerabilities to alien invasive species, develop the most cost-effective options for governments wanting to avoid the high costs of controlling alien invasive species. These include more holistic approaches to biosecurity threats and better resourcing of quarantine and border control operations, including greater inspection and interception capabilities.

12. Assess large engineering projects, such as canals, tunnels and roads that cross biogeographical zones, that might mix previously separated flora and fauna and disturb local biological diversity. Legislation requiring environmental impact assessment of such projects should require an assessment of the risks associated with unintentional introductions of alien invasive species.

13. Have in place the necessary provisions for taking rapid and effective action, including public consultation, should unintentional introductions occur.

5.3 Intentional Introductions – Recommended Actions

1. Establish an appropriate institutional mechanism such as a ‘biosecurity’ agency or authority as part of legislative reforms on invasives. (Refer to Section 9.) This is a very high priority, since at present the legislative framework of most countries rarely treats intentional introductions in a holistic manner, that is, considers all organisms likely to be introduced and their effect on all environments. The usual orientation is towards sectors, e.g. agriculture. Consequently the administrative and structural arrangements are usually inadequate to deal with the entire range of incoming organisms, the implication for the environments into which they are being introduced, or with the need for rapid responses to emergency situations.

2. Empower the biosecurity agency, or other institutional mechanism, to reach decisions on whether proposed introductions should be authorised, to develop import and release guidelines and to set specific conditions, where appropriate. (Operational functions should reside with other agencies. See 9.2.1)

3. Give utmost importance to effective evaluation and decision-making processes. Carry out an environment impact assessment and risk assessment as part of the evaluation process before coming to a decision on introducing an alien species. (See Appendix)

4. Require the intending importer to provide the burden of proof that a proposed introduction will not adversely affect biological diversity.

5. Include consultation with relevant organisations within government, with NGOs and, in appropriate circumstances, with neighbouring countries, in the evaluation process.

6. Where relevant, require that specific experimental trials (e.g. to test the food preferences or infectivity of alien species) be conducted as part of the assessment process. Such trials are often required for biological control proposals and appropriate protocols for such trials should be developed and followed.

7. Ensure that the evaluation process allows for the likely environmental impacts, risks, costs (direct and indirect, monetary and non-monetary) benefits, and alternatives, to have been identified and assessed by the biosecurity authority in the importing country. This authority is then in a position to decide if the likely benefits outweigh the possible disadvantages. The public release of an interim

decision, along with related information, should be made with time for submissions from interested parties before the biosecurity agency makes a final decision.

8. Impose containment conditions on an introduction if and where appropriate. In addition, monitoring requirements are often necessary following release as part of management.

9. Regardless of legal provisions, encourage exporters and importers to meet best practice standards to minimise any invasive risks associated with trade, as well as containing any accidental escapes that may occur.

10. Put in place quarantine and border control regulations and facilities and train staff to intercept unauthorised intentional introductions.

11. Develop criminal penalties and civil liability for the consequent eradication or control costs of unauthorised intentional introductions.

12. Ensure that provisions are in place, including the ability to take rapid and effective action to eradicate or control, in the event that an unauthorised introduction occurs, or that an authorised introduction of an alien species unexpectedly or accidentally results in a potential threat of biological invasion. (See Sections 6 and 9.)

13. As well as taking the efforts that are required at global and regional levels to reduce the risk that trade will facilitate unintentional introductions (Section 5.2), utilise opportunities to improve international instruments and practices relating to trade that affect intentional introductions. For example, the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are addressing the implications alien invasive species may have on the operation of the Convention. Similar initiatives should be made with respect to relevant international trade authorities and industry associations.

6. ERADICATION AND CONTROL

When a potential or actual alien invasive species has been detected, in other words, when prevention has not been successful, steps to mitigate adverse impacts include eradication, containment and control. Eradication aims to completely remove the alien invasive species. Control aims for the long term reduction in abundance or density of the alien invasive species. A special case of control is containment, where the aim is to limit the spread of the alien invasive species and to contain its presence within defined geographical boundaries.

6.1 Guiding Principles

- Preventing the introduction of alien invasive species should be the first goal.

- Early detection of new introductions of potential or known alien invasive species, together with the capacity to take rapid action, is often the key to successful and cost-effective eradications.

- Lack of scientific or economic certainty about the implications of a potential biological alien invasion should not be used as a reason for postponing eradication, containment or other control measures.

- The ability to take appropriate measures against intentionally or unintentionally introduced alien invasive species should be provided for in legislation.

- The best opportunities for eradicating or containing an alien invasive species are in the early stages of invasion, when populations are small and localised. (These opportunities may persist for a short or long time, depending on the species involved and other local factors.)

- Eradication of new or existing alien invasive species is preferable and is more cost effective than long-term control, particularly for new cases.

- Eradication should not be attempted unless it is ecologically feasible and has the necessary financial and political commitment to be completed.

- A strategically important focus for eradication is to identify points of vulnerability in the major invasive pathways, such as international ports and airports, for monitoring and eradication activities.

6.2 Eradication – Recommended Actions

1. Where it is achievable, promote eradication as the best management option for dealing with alien invasive species where prevention has failed. It is much more cost effective financially than ongoing control, and better for the environment. Technological improvements are increasing the number of situations where eradication is possible, especially on islands. Eradication is likely to be more difficult in the marine environment**.** The criteria that need to be met for eradication to succeed are given in the Appendix.

2. When a potentially alien invasive species is first detected, mobilise and activate sufficient resources and expertise quickly. Procrastination markedly reduces the chances of success. Local knowledge and community awareness can be used to detect new alien invasions. Depending on the situation, a country's response might be within the country, or may require a cooperative effort with other countries.

3. Give priority to eradication at sites where a new alien invasion has occurred and is not yet well established.

4. Ensure eradication methods are as specific as possible with the objective of having no long-term effects on non-target native species. Some incidental loss to non-target species may be an inevitable cost of eradication and should be balanced against the long-term benefits to native species.

5. Ensure that persistence of toxins in the environment does not occur as a result of eradication. However, the use of toxins that are unacceptable for long-term control may be justified in brief and intensive eradication campaigns. The costs and benefits of the use of toxins need to be carefully assessed in these situations.

6. Ensure that methods for removing animals are as ethical and humane as possible, but consistent with the aim of permanently eliminating the alien invasive species concerned.

7. Given that interest groups may oppose eradication for ethical or self-interest reasons, include a comprehensive consultation strategy and develop community support for any proposed eradication as an integral part of the project.

8. Give priority to the eradication of alien invasive species on islands and other isolated areas that have highly distinctive biodiversity or contain threatened endemics.

9. Where relevant, achieve significant benefits for biological diversity by eradicating key alien mammalian predators (e.g. rats, cats, mustelids, dogs) from islands and other isolated areas with important native species. Similarly, target key feral and alien mammalian herbivores (e.g. rabbits, sheep, goats, pigs) for eradication to achieve significant benefits for threatened native plant and animal species.

10. Seek expert advice where appropriate. Eradication problems involving several species are often complex, such as determining the best order in which to eradicate species. A multidisciplinary approach might be best, as recommended in the IUCN Guidelines for Re-introductions.

6.3 Defining the Desired Outcomes of Control

The relevant measure of success of control is the response in the species, habitat, ecosystem or landscape that the control aims to benefit. It is important to concentrate on quantifying and reducing the damage caused by alien invasives, not concentrating on merely reducing numbers of alien invasives. Rarely is the relationship between pest numbers and their impacts a simple one. Hence estimating the reduction in the density of the alien invasive species will not necessarily indicate an improvement in the wellbeing of the native species, habitat or ecosystem that is under threat. It can be quite difficult to identify and adequately monitor the appropriate measures of success. It is important to do so, however, if the main goal, namely preventing the loss of biodiversity, is to be achieved.

6.4 Choosing Control Methods

Control methods should be socially, culturally and ethically acceptable, efficient, non-polluting, and should not adversely affect native flora and fauna, human health and well-being, domestic animals, or crops. While meeting all of these criteria can be difficult to achieve they can be seen as appropriate goals, within the need to balance the costs and benefits of control against the preferred outcomes.

Specific circumstances are so variable it is only possible to give broad guidelines of generally favoured methods: specific methods are better than broad spectrum ones. Biological control agents may sometimes be the preferred choice compared to physical or chemical methods, but require rigorous screening prior to introduction and subsequent monitoring. Physical removal can be an effective option for clearing areas of alien invasive plants. Chemicals should be as specific as possible, non-persistent, and non-accumulative in the food chain. Persistent organic pollutants, including organochlorine compounds should not be used. Control methods for animals should be as humane as possible, consistent with the aims of the control.

6.5 Control Strategies – Recommended Actions

Unlike eradication, control is an ongoing activity that has different aims and objectives. While there are several different strategic approaches that can be adopted they should have two factors in common. First, the outcomes that are sought need to achieve gains for native species, be clearly articulated, and widely supported. Second, there needs to be management and political commitment to spend the resources required over time to achieve the outcomes. Badly focused and half-hearted control efforts can waste resources which might be better spent elsewhere.

Recommended actions are as follows:

1. Prioritise the alien invasive species problems according to desired outcomes. This should include identifying the areas of highest value for native biological diversity and those most at risk from alien invasives. This analysis should take into account advances in control technology and should be reviewed from time to time.

2. Draw up a formal control strategy that includes identifying and agreeing to the prime target species, areas for control, methodology and timing. The strategy may apply to parts of, or to a whole country, and should have appropriate standing as, for example, the requirements of Article 6 of the Convention on Biological Diversity ("General Measures for Conservation and Sustainable Use"). Such strategies should be publicly available, be open for public input, and be regularly reviewed.

3. Consider stopping further spread as an appropriate strategy when eradication is not feasible, but only where the range of the alien invasive is limited and containment within defined boundaries is possible. Regular monitoring outside the containment boundaries is essential, with quick action to eradicate any new outbreaks.

4. Evaluate whether long-term reduction of alien invasive numbers is more likely to be achieved by adopting one action or set of linked actions (multiple action control). The best examples of single actions come from the successful introduction of biological control agent(s). These are the 'classical' biological control programs. Any intentional introductions of this nature should be subject to appropriate controls and monitoring. (See also Sections 5.3, 9 and Appendix.) Exclusion fencing can be an effective single action control measure in some circumstances. An example of multiple action control is integrated pest management which uses biological control agents coupled with various physical and chemical methods at the same time.

5. Increase the exchange of information between scientists and management agencies, not only about alien invasive species, but also about control methods. As techniques are continuously changing and improving it is important to pass this information on to management agencies for use.

6.6 Game and Feral Species as Alien Invasives – Recommended Actions

Feral animals can be some of the most aggressive and damaging alien species to the natural environment, especially on islands. Despite any economic or genetic value they may have, the conservation of native flora and fauna should always take precedence where it is threatened by feral species. Yet some alien invasive species that cause severe damage to native biodiversity have acquired positive cultural values, often for hunting and fishing opportunities. The result can be conflict between management objectives, interest groups and communities. In these circumstances it takes longer to work through the issues, but resolution can often be achieved through public awareness and information campaigns about the damaging impacts of the alien invasives, coupled with consultation and adaptive management approaches that have community support. Risk analysis and environmental impact assessment may also help to develop appropriate courses of action and solutions.

Recommended actions are as follows:

1. Consider managing hunting conflicts on public land by designating particular areas for hunting while carrying out more stringent control to protect biodiversity values elsewhere. This option is limited in its application to situations where there is high value attached to the alien species and yet biological diversity values can still be protected through localised action.

2. Evaluate the option of removal of a representative number of the feral animals to captivity or domestication where eradication in the wild is planned.

3. Strongly encourage owners and farmers to take due care to prevent the release or escape of domestic animals that are known to cause damage as feral animals, e.g. cats, goats.

4. Develop legal penalties to deter such releases and escapes in circumstances where costly economic or damaging ecological consequences are likely to follow.

7. LINKS TO RE-INTRODUCTION OF SPECIES

7.1 Guiding Principle

❖ Successful eradications and some control programmes can significantly improve the likely success of re-introductions of native species, and thereby provide opportunities to reverse earlier losses of native biological diversity.

7.2 Links Between Eradication and Control Operations and Re-introductions

An eradication operation that successfully removes an alien invasive species, or a control operation that lowers it to insignificant levels, usually improves the conditions for native species that occupy or previously occupied that habitat. This is especially true on many oceanic islands. Eradications are often undertaken as part of the preparation for re-introduction(s).

The IUCN Guidelines for Re-introductions (May 1995) were developed to provide "...direct, practical assistance to those planning, approving or carrying out re-introductions." These guidelines elaborate requirements and conditions, including feasibility studies, criteria for site selection, socio-economic and legal requirements, health and genetic screening of individuals, and issues surrounding the proposed release of animals from captivity or rehabilitation centres. They should be referred to as part of the planning of eradication or control operations where re-introductions might be an appropriate and related objective. They should also be referred to if reviewing any re-introduction proposal.

The socio-economic considerations that apply to eradication and control operations largely apply to re-introductions as well, namely the importance of community and political support, financial commitment and public awareness. This makes it cost-effective to combine consultation over the eradication objective with proposals to re-introduce native species. It has the added advantage of offsetting the negative aspects of some eradications (killing valued animals) with the positive benefits of re-introducing native species (restoring heritage, recreation or economic values).

8. KNOWLEDGE AND RESEARCH ISSUES

8.1 Guiding Principle

❖ An essential element in the campaigns against alien invasive species at all levels (global, national, local) is the effective and timely collection and sharing of relevant information and experiences, which, in turn, assist advances in research and better management of alien invasive species.

8.2 Recommended Actions

1. Give urgency to the development of an adequate knowledge base as a primary requirement to address the problems of alien invasive species worldwide. Although a great deal is known about many such species and their control, this knowledge remains incomplete and is difficult to access for many countries and management agencies.

2. Contribute to the development of an easily accessible global database (or linked databases) of all known alien invasive species, including information on their status, distribution, biology, invasive characteristics, impacts and control options. It is important that Governments, management agencies and other stakeholders should all participate in this.

3. Develop "Black Lists " of alien invasive species at national, regional and global levels that are easily accessible to all interested parties. While "Black Lists" are a useful tool for focusing attention on known alien invasive species, they should not be taken to imply that unlisted alien species are not potentially harmful.

4. Through national and international research initiatives**,** improve knowledge of the following: ecology of the invasion process, including lag effects; ecological relationships between invasive species; prediction of which species and groups of species are likely to become invasive and under what conditions; characteristics of alien invasive species; impacts of global climate change on alien invasive species; existing and possible future vectors; ecological and economic losses and costs associated with introductions of alien invasive species; sources and pathways caused by human activity.

5. Develop and disseminate better methods for excluding or removing alien species from traded goods, packaging material, ballast water, personal luggage, aircraft and ships.

6. Encourage and support further management research on: effective, target-specific, humane and socially acceptable methods for eradication or control of alien invasive species; early detection and rapid response systems; development of monitoring techniques; methods to gather and effectively disseminate information for specific audiences.

7. Encourage monitoring, recording and reporting so that any lessons learned from practical experiences in management of alien invasive species can contribute to the knowledge base.

8. Make better use of existing information and experiences to promote wider understanding and awareness of alien invasive species issues. There need to be strong linkages between the actions taken under Sections 4 and 8.

9. LAW AND INSTITUTIONS

9.1 Guiding Principles

- A holistic policy, legal and institutional approach by each country to threats from alien invasive species is a prerequisite to conserving biological diversity at national, regional and global levels.

- Effective response measures depend on the availability of national legislation that provides for preventative as well as remedial action. Such legislation should also establish clear institutional accountabilities, comprehensive operational mandates, and the effective integration of responsibilities regarding actual and potential threats from alien invasive species.

- Cooperation between countries is needed to secure the conditions necessary to prevent or minimise the risks from introductions of potentially alien invasive species. Such cooperation is to be based on the responsibility that countries have to ensure that activities within their jurisdiction or control do not cause damage to the environment of other countries.

9.2 Recommended Actions

9.2.1 National level

1. Give high priority to developing national strategies and plans for responding to actual or potential threats from alien invasive species, within the context of national strategies and plans for the conservation of biological diversity and the sustainable use of its components.

2. Ensure that appropriate national legislation is in place, and provides for the necessary controls of intentional and non-intentional introductions of alien species, as well as for remedial action in case such species become invasive. Major elements of such legislation are identified in previous sections, particularly sections 5 and 6.

3. Ensure that such legislation provides for the necessary administrative powers to respond rapidly to emergency situations, such as border detection of potential alien invasive species as well as to address threats to biological diversity caused by intentional or non-intentional introductions of alien species across biogeographical boundaries within one country.

4. Ensure, wherever possible, for the designation of a single authority or agency responsible for the implementation and enforcement of national legislation, with clear powers and functions. In cases where this proves impossible, ensure there is a mechanism to coordinate administrative action in this field, and set up clear powers and responsibilities between the administrations concerned. (Note : these operational roles regarding implementation and enforcement are different from, and in addition to the specific function of the 'biosecurity' agency that was recommended in Section 5.3.)

5. Review national legislation periodically, including institutional and administrative structures, in order to ensure that all aspects of alien invasive species issues are dealt with according to the state of the art, and that the legislation is implemented and enforced.

9.2.2 International level

1. Implement the provisions of international treaties, whether global or regional, that deal with alien invasive species issues and constitute a compulsory mandate for respective Parties. Most prominent among these treaties is the Convention on Biological Diversity, and a number of regional accords.

2. Implement decisions taken by Parties to specific global and regional conventions, such as resolutions, codes of conduct or guidelines related to introductions of alien species, for example the International Maritime Organisation's guidance on ballast water.

3. Consider the desirability, or as the case may be, necessity, of conducting further agreements, on a bilateral or multilateral basis, or adapting existing ones, with respect to the prevention or control of introduction of alien species. This includes, in particular, consideration of international agreements related to trade, such as those under the auspices of the World Trade Organisation.

4. For neighbouring countries, consider the desirability of cooperative action to prevent potential alien invasive species from migrating across borders, including agreements to share information, through, for example, information alerts, as well as to consult and develop rapid responses in the event of such border crossings.

5. Generally develop international cooperation to prevent and combat damage caused by alien invasive species, and provide assistance and technology transfer as well as capacity building related to risk assessment as well as management techniques.

10. ROLE OF IUCN

1. IUCN will continue to contribute to the Global Invasive Species Programme (GISP)[4], together with CAB International, the United Nations Environment Programme (UNEP) and the Scientific Committee on Problems of the Environment (SCOPE).

2. IUCN will actively participate in the processes and meetings of the Convention on Biological Diversity (CBD) to implement article 8(h) by providing scientific, technical and policy advice.

3. The components of IUCN (including its Commissions, Programmes and Regional Offices) will act together to support the IUCN Global Initiative on Invasive Species.

4. IUCN will maintain and develop links and cooperative programmes with other organisations involved in this issue, including international organisations such as the United Nations Environment Programme, Food and Agricultural Organisation, Scientific Committee on Problems of the Environment, World Trade Organisation and international NGOs. IUCN will work with work with Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Parties to the Convention on Biological Diversity (CBD), Parties to the RAMSAR Convention, and with regional programmes such as the South Pacific Regional Environment Programme (SPREP).

[4] SCOPE, UNEP, IUCN and CABI have embarked on a programme on invasive species, with the objective of providing new tools for understanding as well as dealing with invasive species. This initiative is called the Global Invasive Species Programme (GISP). GISP engages the many constituencies involved in the issue, including scientists, lawyers, educators, resource managers and people from industry and government. GISP maintains close cooperation with the CBD Secretariat on the issue of alien species.

5. IUCN regional networks will play a significant role in raising public awareness at all levels on the issues of alien invasive species, the various threats to native biological diversity and the economic implications, as well as options for control.

6. The IUCN Invasive Species Specialist Group (ISSG) of the Species Survival Commission (SSC) will, through its international network, continue to collect, organise and disseminate information on alien invasive species, on prevention and control methods, and on ecosystems that are particularly vulnerable to alien invasion.

7. The separate work of IUCN/SSC on identifying species threatened with extinction and areas with high levels of endemism and biodiversity will be supported. This work is valuable when assessing alien invasion risks, priority areas for action, and for practical implementation of these guidelines.

8. The ongoing work of the ISSG will be supported, including the following actions: the development and maintenance of a list of expert advisors on control and eradication of alien invasive species; expansion of the alien invasive species network; production and distribution of newsletters and other publications.

9. IUCN, in association with other cooperating organisations, will take a lead in the development and transfer of capacity building programmes (e.g. infrastructure, administration, risk and environmental assessment, policy, legislation), in support of any country requesting such assistance or wishing to review its existing or proposed alien invasive species programmes.

10. IUCN will take an active role in working with countries, trade organisations and financial institutions (e.g. World Trade Organisation, World Bank, International Monetary Fund, International Maritime Organisation) to ensure that international trade and financial agreements, codes of practice, treaties and conventions take into account the threats posed to biological diversity and the financial costs and economic losses associated with alien invasive species.

11. The ISSG will support the work of the IUCN Environmental Law Programme in assisting countries to review and improve their legal and institutional frameworks concerning alien invasive species issues.

12. The ISSG will develop regional databases and early warning systems on alien invasive species and work with other cooperating organisations to ensure efficient and timely dissemination of relevant information to requesting parties.

11. BIBLIOGRAPHY AND RELATED INFORMATION

The guiding principles and text of these guidelines are partially based on, or sourced from the following important documents:

Translocation of Living Organisms. IUCN Position Statement, 1987. IUCN, Gland, Switzerland.

IUCN Guidelines for Re-introductions. 1995. IUCN, Gland, Switzerland.

Code of Conduct of the Import and Release of Exotic Biological Control Agents. United Nations Food and Agriculture Organisation, 1995. FAO, Rome, Italy.

Harmful Non-indigenous Species in the United States. U.S. Congress, Office of Technology Assessment, OTA-F-565, 1993. US Government Printing Office, Washington DC.

Proceedings. Norway/UN Conference on Alien Species. The Trondheim Conference on Biodiversity. 1-5 July 1996. Norwegian Institute for Nature Research, Trondheim, Norway.

Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ship's Ballast Water and Sediment Discharges. International Maritime Organisation (IMO) Resolution A.774(18)(4.11.93) (Annex)

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APPENDIX

1. Environmental Impact Assessment (EIA)

Generic questions in the EIA process concerning impacts a proposed introduced species may have on the environment should include the following:

❖ Does the proposed introduction have a history of becoming invasive in other places? If yes, it is likely to do so again and should not be considered for introduction.

❖ What is the probability of the alien species increasing in numbers and causing damage, especially to the ecosystem into which it would be introduced?

❖ Given its mode of dispersal, what is the probability the alien species would spread and invade other habitats?

❖ What are the likely impacts of natural cycles of biological and climatic variability on the proposed introduction? (Fire, drought and flood can substantially affect the behaviour of alien plants.)

❖ What is the potential for the alien species to genetically swamp or pollute the gene pool of native species through interbreeding?

❖ Could the alien species interbreed with a native species to produce a new species of aggressive polyploid invasive?

❖ Is the alien species host to diseases or parasites communicable to native flora or fauna, humans, crops, or domestic animals in the proposed area for introduction?

- What is the probability that the proposed introduction could threaten the continued existence or stability of populations of native species, whether as a predator, as a competitor for food, cover, or in any other way?

- If the proposed introduction is into a contained area(s) with no intention of release, what is the probability of a release happening accidentally?

- What are the possible negative impacts of any of the above outcomes on human welfare, health or economic activity?

2. Risk Assessment

This refers to an approach that seeks to identify the relevant risks associated with a proposed introduction and to assess each of those risks. Assessing risk means looking at the size and nature of the potential adverse effects of a proposed introduction as well as the likelihood of them happening. It should identify effective means to reduce the risks and examine alternatives to the proposed introduction. The proposed importer often does a risk assessment as a requirement by the decision-making authority.

3. Criteria to be Satisfied to Achieve Eradication

- The rate of population increase should be negative at all densities. At very low densities it becomes progressively more difficult and costly to locate and remove the last few individuals.

- Immigration must be zero. This is usually only possible for offshore or oceanic islands, or for very new alien invasions.

- All individuals in the population must be at risk to the eradication technique(s) in use. If animals become bait- or trap-shy, then a sub-set of individuals may no longer be at risk to those techniques.

- Monitoring of the species at very low densities must be achievable. If this is not possible survivors may not be detected. In the case of plants, the survival of seed banks in the soil should be checked.

- Adequate funds and commitment must continuously exist to complete the eradication over the time required. Monitoring must be funded after eradication is believed to have been achieved until there is no reasonable doubt of the outcome.

- The socio-political environment must be supportive throughout the eradication effort. Objections should be discussed and resolved, as far as practicable, before the eradication is begun.

Chapter 21:

CAPTIVE BREEDING OF AMPHIBIANS FOR CONSERVATION

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CONTENTS

Abstract

Captive breeding programmes for amphibians can make contributions to conservation if they are involved with reintroduction, research relevant to wild populations or conservation education. Compared to other vertebrates amphibians possess several life history characteristics that make them potentially model organisms for captive breeding programmes. However, the threats that wild populations face are often difficult to neutralize and the success of reintroductions may be difficult to evaluate without long-term monitoring. Nevertheless, self-sustaining populations of some species have been established by the reintroduction of captive bred animals. Although many captive breeding programmes have adjunct research and education programmes, there has been little evaluation of the impact such activities have on conservation. The role of zoos in captive breeding and conservation programmes is continuing to evolve, but the number of amphibian conservation programmes undertaken by such institutions remains small compared to those of other vertebrate taxa. The organisational infrastructures in place within zoo organisations for managing endangered species may be inappropriate for many amphibian species. Although the private sector has the potential to make important contributions to conservation through captive breeding, harnessing this capability is problematical.

Amphibians as models for captive breeding

Compared to higher vertebrate taxa, amphibians possess several features that make them potentially very appropriate animals for captive breeding programmes (Bloxam & Tonge, 1995; Jones, 2002). Many species display high fecundity and breed at least once per year, and this productivity can be utilized to produce large numbers of progeny quickly, so that captive populations can outgrow the risks posed by the various stochastic processes that impinge on small populations (Caughley, 1994). Moreover, the large numbers of eggs and larvae produced from captive breeding programmes are rarely dependent on long periods of parental care. Compared to mammals and birds, amphibians display a high degree of genetically programmed behavioural and physiological traits. This means that providing certain basic environmental parameters are replicated in captivity (e.g. appropriate cycles of temperature, moisture and light) many species will behave naturally and breed well. Moreover, the type of aberrant behaviours that are often observed in endotherms that have a high a degree of learnt behaviour and/or complex social systems (e.g. Shepherdson, 1994) are not manifested in amphibians. Likewise, when it comes to reintroductions into the wild, periods of pre-release training to ensure that animals can recognize appropriate food and natural enemies can be circumvented altogether. Finally, because of their small size and relatively straightforward food, space and general maintenance requirements, amphibians are cost-effective animals to maintain in captivity – it is estimated that the cost of the entire Mallorcan midwife toad breeding unit at Jersey Zoo cost just $150 (Bloxam & Tonge, 1995). It is therefore possible to maintain large, viable populations in captivity relatively cheaply and without overburdening available cage space.

Are then, amphibians truly model organisms for captive breeding programmes for conservation? Of course, simply breeding species that are of conservation interest in captivity does not constitute a contribution to conservation in its own right. In this chapter, we adopt the stance that captive breeding can make a positive contribution to the conservation of amphibians if it is directly involved with reintroduction, research that is relevant to the conservation of wild populations, or public education. These three criteria are consistent with those for licensing animal collections that are open to the public in many parts of the world (e.g. Zoo Licensing Act in the UK; European Community Zoos Directive 2002). In order to explore how well amphibians are meeting these criteria it is necessary to consider the captive breeding of amphibians in terms of wider conservation strategies and priorities. For example, Balmford et al. (1996) distinguish between ex situ conservation as a temporary holding measure prior to reintroduction to the wild and long-term captive breeding of species that are unlikely to ever be reintroduced: 'Wherever possible captive breeding efforts should be primarily directed toward the long-term recovery of wild populations'. This may be achieved via ex situ support activities, such as fund raising, education programmes and secondment of staff to field programmes.

Reintroductions

The wider issue of amphibian translocations is dealt with in Chapter 20 of this volume, and has previously been discussed within the critiques by Dodd & Seigel (1991), Seigel & Dodd (1992) and Dodd (2005). Here we will therefore focus on those issues that are particularly relevant to the reintroduction of captive bred animals.

Reintroduction of animals to the wild has frequently been promoted as the primary reason for breeding animals in captivity (e.g. Tudge, 1991; Balmford et al., 1996). However, for many amphibian species, reintroductions may be achieved more efficiently, more safely and more cost-effectively if they do not involve a captive breeding component. Simple translocation of spawn or tadpoles, for example, can be an effective tool in species recovery. In Britain, there have been 20 reintroductions of natterjack toads (*Bufo calamita*) using translocation of spawn between sites. Fourteen of these reintroductions have shown signs of success, and at least six have resulted in the establishment of stable breeding populations (Denton et al., 1997). Captive breeding has been used as an adjunct to the wild-wild translocations of natterjack toads, but the main benefit of the programme has probably been raising public awareness (e.g. Edgar, 1990). Where high levels of spawn or tadpole mortality are prevalent, head-starting tadpoles by raising them beyond the stages at which they are vulnerable to competitors and predators may also be preferable to captive breeding.

An analysis by Beck et al. (1994) revealed that up to that time there were 23 reintroduction projects of captive bred reptiles and amphibians (the two classes were pooled in their analysis) covering some 22 species and 31 483 individuals. Since the review by Beck et al. (1994) there have been further cases of reintroductions of captive bred amphibians to the wild. A more recent analysis by Pavajeau (2005) showed that 101 amphibian species have been involved in captive breeding or release activities for conservation purposes. Of these, 28 species have been used for releases that did not involve captive breeding, with a further 23 species in breeding programmes that have releases into the wild as one of the aims (Tables 1-2). This suggests that captive breeding for reintroduction has increased in popularity as a conservation tool in recent years.

When reintroduction is a prime reason for carrying out captive breeding, then serious consideration should be given to the nature of the threats facing the species in the wild. The most successful animal reintroductions have usually involved those species that have threats that are easily neutralized (e.g. Griffith et al. 1989; Wilson & Stanley Price, 1994). Threats that are more likely to be reversible are often those associated with direct persecution, pollution and introduced species. These are threats can sometimes be realistically addressed using legal, political or cultural processes that are enforceable. One problem facing amphibians is that the threats that they face are complex, often synergistic, and not easily reversed (Kiesecker et al., 2001; Collins & Storfer, 2003; Beebee & Griffiths, 2005). In particular, those threats associated with habitat loss and climate change will be difficult to ameliorate – let alone reverse – even over long timeframes. If reintroduction is the main purpose of a captive breeding programme, the reversibility of threats should influence which species are considered for such programmes. Although it has been suggested that if the golden toad (*Bufo periglenes*) had been established in captivity it would not have gone extinct (e.g. Harding, 1993), reintroduction would have been a doubtful proposition as the agent of extinction remains complex and – at present – irreversible (e.g. Pounds & Crump, 1994; Pounds et al., 1999). For those species threatened by more localised agents of decline – such as introductions of fish or other predators – reversing the threats may be more feasible (see Chapter 9). In some cases, though, this too might be difficult. One of the main threats facing the Mallorcan midwife toad (*Alytes muletensis*) is predation by the introduced viperine snake (*Natrix maura*). Because these predators are relatively widespread and have cryptic lifestyles, eliminating them is problematical. However, analysis of the habitat requirements and geographical ranges of both toad and predator can assist in the identification of potential sites for reintroduction within areas of non-overlap (Moore et al., 2004).

Probably the most pressing challenges for amphibian captive breeding programmes are those concerned with population genetics and disease. High egg and larval mortality is a natural – and often density-dependent – process in amphibian life history and exerts strong selection pressures that may have consequences for how well populations are adapted to their environments. In captivity, these selection pressures are removed and high survival can be achieved while generating large numbers of offspring. The problem is therefore whether certain fitness traits may be lost through multiple generations of captive breeding, and captive populations become adapted to the captive environment through artificial selection (Woodworth et al., 2002; Gilligan & Frankham, 2003). Certainly, there is evidence that this can occur in fish populations (e.g. Säisä et al. 2003), but data on amphibians are lacking. Indeed, the only threatened amphibian in which this has been studied is the Mallorcan midwife toad. In this species, innate responses to introduced predators were retained in captive populations, at least for a few generations. Equally, captive populations retained levels of heterozygosity that were comparable to wild populations over the same period. However, long-term captive breeding resulted in a reduction in the ability to respond to predators, coupled with a reduction in heterozygosity (Kraaijeveld-Smit et al., in press).

The topic of emerging infectious diseases has recently received wide attention in wildlife conservation and in the amphibian decline debate in particular (e.g. Cunningham, 1996; Daszak et al., 2003). There is no doubt that there is a high potential for disease transmission within captive populations of amphibians, particularly when they are housed in close proximity to other species from different parts of the world, as is typical in zoos and aquaria. When sensitive, threatened species are being captive bred for reintroduction purposes, isolated quarantine-type facilities are needed for maintaining populations. Equally, very rigorous health screening is therefore necessary before animals from captive populations should be considered for reintroduction.

If an amphibian reintroduction programme does go ahead, there is debate concerning how ‘success’ should be defined. During follow-up monitoring, there are three fundamental levels at which ‘success’ might be regarded as having been achieved. The lowest level is confirming that released animals are surviving at the reintroduction site. This might demonstrate that animals are able to feed and perhaps display other behavioural repertoires reasonably normally, but is insufficient evidence for long-term viability. A better measure of success involves determining whether released animals have bred successfully in the wild. However, even successful breeding may not result in the establishment of a self-sustaining population if the number of animals is below the threshold for a minimum viable population or stochastic processes play an important part in regulating population size. The highest – and most rigorous – level at which the success of reintroduction may be determined is by establishing whether a self-sustaining, viable population is present in the long-term. This will involve monitoring populations for several generations.

As far as amphibian captive breeding and reintroduction programmes are concerned, long-term monitoring to establish viability presents several problems. Firstly, many species have cryptic lifestyles that make them difficult to monitor outside periods when they aggregate at breeding sites. Consequently, much survey effort is focused on carrying out censuses at breeding sites for the relatively short periods that species are engaged in reproduction. Recent work on amphibians has shown that estimates of census population size and breeding population size can overestimate the effective population size (e.g. Jehle et al., 2001; Rowe & Beebee, 2004). Effective population size has been determined for very few species of amphibian, and as such measures are required to generate reliable predictions about viability, it may be difficult to know whether even well monitored populations are viable in the long-term. A second issue concerns the methods that are currently widely used to carry out amphibian population monitoring. Very often, such methods rely on simple counts - often standardized by sampling effort - and repeated at different sites or at the same site over a time period. As Schmidt (2003, 2004) points out, such simple counts do not take account of detection probabilities, and even when standardized may yield unreliable measures of population size. Mark-recapture, distance sampling or Bayesian models are needed to account for temporal or spatial variation in detection probabilities if this problem is to be overcome. Thirdly, there is the problem of amphibian population fluctuations. Wide natural variation in population size has been demonstrated for many species (e.g. Pechmann et al., 1991), and this characteristic may extend the number of generations required for monitoring even further if a long-term trend is to be established. Fourthly, many amphibian species appear to function as metapopulations (e.g. Marsh & Trenham, 2001), and this needs to be taken into account within any captive breeding and reintroduction programme. If a species is completely extinct within a region, the reintroduction programme may need to focus on establishing several functionally connected subpopulations simultaneously if the project is likely to stand a chance of succeeding. However, our knowledge of the population biology of threatened amphibians is usually imperfect, and designing an appropriate landscape for such a species that is strongly rooted in science may be difficult. Alternatively, a reintroduction may focus on establishing new subpopulations to reinforce an existing metapopulation of the species concerned. In such a scenario, direct contact between captive-raised and wild animals of the same species raises serious issues, not the least of which is the risk of disease transmission. However, this type of reintroduction also raises problems with long-term monitoring, as it may not be clear whether a successfully established metapopulation was the direct result of the reintroduction, natural recolonization of a site by wild animals, or a combination of the two.

Despite these caveats, there is good collective evidence that reintroduction of captive bred amphibians has been successful at least to the level of establishing breeding populations, in species that have been studied long-term. Reintroductions of captive-bred Mallorcan midwife have been carried out on a regular basis since 1989, in conjunction with habitat assessment and management and ongoing monitoring (Bloxam & Tonge, 1995; Buley & García, 1997). Twelve new breeding sites have been established in the wild through the release of captive bred animals. These now support about 25% of the current wild population and have doubled the species' geographical range (Buley & Gonzalez-Villavicencio, 2000). The improvement in the status of the species has led to it being down-listed from 'critically endangered' to 'threatened' in the IUCN Red List. Reintroductions of captive bred tadpoles and toadlets of the Puerto Rican crested toad (*Bufo lemur*) to newly created ponds have been carried out as part of a co-ordinated Species Survival Plan (SSP) by North American zoos (Johnson, 1999). Adult toads returned to these ponds and bred successfully following the release of about 10,000 tadpoles annually for a 10 year period (Johnson, pers comm.). What these two studies demonstrate is that the execution and monitoring of amphibian reintroductions is a long-haul process. Pavajeau (2005) cites a further six species that have shown evidence of breeding in the wild following the reintroduction of captive bred stock: European treefrog (*Hyla arborea*), natterjack toad (*Bufo calamita*), Wyoming toad (*Bufo baxteri*), agile frog (*Rana agilis*), Ramsey canyon leopard frog (*Rana subaquvocalis*) and Romer's treefrog (*Chirixalis romeri*). However, in at least two of these programmes (natterjack toad in England and agile frog on the island of Jersey) captive breeding formed a relatively minor component within wider programmes that mainly used head-starting or translocation of spawn or tadpoles.

Although Dodd & Seigel (1991), Seigel & Dodd (1992) and Dodd (2005) rightly point out that 'success' can never truly be established unless a self-sustaining population is established, for most amphibian species demonstrating this is – at best – extremely difficult, and may require a monitoring programme that extends beyond the lifespan of the average researcher. Whether or not they involve captive breeding, reintroduction programmes for amphibians are at an early stage of development, and it will be many years before we can make unqualified judgements concerning their effectiveness as a tool for conservation. Certainly more science is needed, but given the current biodiversity crisis, we cannot wait for all the necessary hypotheses to be rigorously tested before acting. Adaptive management – which relies on continuous review and refinement of programme protocols based on prior experience - will therefore always be an integral part of amphibian captive breeding and reintroduction, and of conservation programmes in general.

Research

Scientific research that is associated with captive breeding programmes for amphibians can take several forms. Such research can be classified as (1) work primarily aimed at improving captive husbandry, animal welfare and maintenance and (2) work primarily aimed at improving the status of wild populations (Table 3). These two broad categories are not mutually exclusive as, for example, research on genetics and reproductive biology – even if carried out on captive bred animals – may be highly relevant to the management of both captive and wild populations. On the other hand, research on the nutritional requirements of captive frogs may be of only marginal relevance to the conservation of wild populations.

As many amphibian species have cryptic and secretive lifestyles, there are many aspects of their biology that are easier to study in captivity than in the wild. These include social behaviour, feeding habits and reproductive biology. Additionally, there are certain standard physiological values (e.g. blood, tissue, faecal measures) that may be more conveniently measured in captive animals, although comparative data from wild stock should be obtained whenever possible (Wiese & Hutchins, 1994).

Table 3 summarizes information on conservation-related research that has been carried out in conjunction with amphibian captive breeding programmes. The data are not comprehensive in that not all research that may be used to inform conservation management is published in peer-reviewed journals. Equally, the Table does not show information on species that have a well-documented conservation research record that has not directly involved research on captive populations (e.g. natterjack toad). Certainly, some of the research carried out on captive amphibian populations has had wider scientific implications. Work on the Montserrat mountain chicken, for example, has revealed a novel method of tadpole provisioning by female frogs (Gibson & Buley, 2003). Equally, genetic work on the Mallorcan midwife toad has shed light on the wider evolutionary relationships within the genus *Alytes* (Arntzen et al., 1995).

What is clear is that relatively little research from captive breeding and reintroduction programmes is being published in the peer-reviewed literature. Out of the 23 species identified by Pavajeau (2005) as being in captive breeding programmes with potential for reintroduction, 16 had no papers published on issues related to conservation in journals listed in the Web of Science. Of the remaining species, six had 1-5 papers published. The seventh species – the Mallorcan midwife toad – had over 11 papers published. Several of these deal with reproductive biology, while others cover the impact of predators and population genetics.

Collaboration between institutions that maintain captive populations of amphibians and scientists is increasing, and can be mutually beneficial and cost-effective for both parties (e.g. Marcellini & Murphy, 1998). For example, by working with scientists, zoos and aquaria can achieve their conservation mission statements; at the same time scientists can work with captive populations while making a substantial saving on animal maintenance costs from their research grants. Despite this encouraging trend, as Table 3 shows there are relatively few published studies that have shown that research on captive amphibians has resulted in direct transferable benefits for wild populations. The most frequently published work emerging from captive breeding programmes concerns husbandry protocols. A few species have published information on reintroduction protocols, but work on genetics, reproductive biology or health monitoring has been published for only eight species (Table 3). Card et al. (1998) highlight the shortcomings in formal research and conservation by herpetology departments in North American zoos. Much of the research lacks direction, and most of the published research has been done by a small number of institutions (Card et al., 1998). This may be partly due to the fact that conservation research on amphibians in zoos is in its infancy. For example, research on chytridiomycosis in captive frogs may well have implications for the management of wild frog populations sometime in the future (Nichols et al., 2001). Nevertheless, it is fair to say that at present, conservation research involving captive amphibian populations has yet to realise its potential.

Conservation Education

Amphibian captive breeding programmes have the potential to indirectly benefit conservation through both formal and informal education. Formal education programmes can use captive animals as integral components of school, college or University curricula; informal education programmes consist of non-curricula educational provision for the wider general public. Informal education should be a component of both in situ and ex situ conservation programmes. In situ conservation education programmes focus on raising awareness, understanding and knowledge among local people. The recovery programmes for the Puerto Rican crested toad and the Mallorcan midwife toad, for example, both have strong captive breeding components and the institutions involved with the breeding programme have been directly involved with educational provision in Puerto Rica and beyond. These include the production of materials for local schools and visitor centres together with a wide variety of material publicising the plight of these species. However, breeding centres do not necessarily have to be involved with reintroduction in order to do in situ education about conservation. The Indiana University axolotl colony, for example, is primarily involved with breeding axolotls for laboratory-based research and is not involved with reintroduction, but still supports an outreach education programme within the local community at Lake Xochimilco, Mexico – the last remaining habitat for wild axolotls.

Education departments of zoos run programmes for school groups that are usually linked to formal curricula and these may include elements of amphibian life history, evolution and conservation. The International Training Centre at Durrell Wildlife Conservation Trust (Jersey Zoo) runs courses at certificate and Diploma level for students and conservation professionals that embrace amphibian conservation issues (Fa et al., 1995; Fa & Clark, 1997). Some of the students undertake projects that are directly related to in situ amphibian conservation programmes, and go on to use their training in field conservation programmes. Some other zoos have run short courses with a focus on amphibian captive breeding and conservation.

Informal education in zoos has evolved from providing just a basic labelling system to a diversity of activities that aim to engage and stimulate visitor interest interactively by using different media. Although exhibit development within zoos has sometimes incorporated educational messages about amphibians (e.g. Marcellini & Murphy, 1998) there are few data available to show how effective these are in improving the knowledge or attitudes of visitors. As evaluation surveys are often focused on ‘reptile houses’ or ‘herps’ in general, it is difficult to extract information that is specific to amphibians. In three North American zoos, the traditional reptile houses were converted into ‘Reptile Discovery Centres’ by providing new interactive visitor interpretation. Visitors spent much longer in the exhibits after the conversion, and demonstrated improved knowledge and attitudes towards reptiles and amphibians (Marcellini & Murphy, 1998). Wider surveys of zoo visitors have yielded mixed results. Visitor tracking surveys carried out at Jersey Zoo – an institution dedicated to wildlife conservation – showed that visitors spent less time reading signs in the reptile house (where some amphibians are also displayed) than they did in other sections of the zoo. Equally, a questionnaire survey showed that visitors left the zoo with an improved knowledge of birds and mammals, but no improvement in their knowledge of reptiles (Broad, 1996). These results are consistent with the findings of MacGregor (1994), who found that visitors passing through London Zoo’s reptile house showed no evidence of any improvement in attitudes or knowledge, despite some prominent interpretation displays within the facility.

Observations of how much time visitors spend at different exhibits may also provide an indication of the effectiveness of different types of displays. At the National Zoo in Washington, visitors spent less time observing amphibians than any other display in the reptile house (Marcellini & Jenssen, 1988). In contrast, at Jersey Zoo the poison dart frogs were ranked fourth out of fifteen displays in terms of time spent at each exhibit by visitors (Phillpot, 1996). Although there may be general trends for visitors to spend more time at exhibits that display larger animals, the frogs in Jersey Zoo’s reptile house were the smallest animals on display. The holding power of the frogs may lie with the nature of the display – an attractive enclosure well planted with lush vegetation stimulates the visitor to search out the animals. The educational value of the exhibit may therefore be enhanced by such interactive experiences (Phillpot, 1996).

Of course, there are several factors unrelated to the type of education provision that might influence such results, such as the population from which the sample of zoo visitors is drawn, the design of the building, the resources allocated to different sections, and the intrinsic appeal of different animals to the general public. Most zoo visitor surveys focus only on short-term changes in visitor attitudes and knowledge that may be misleading in terms of long-terms implications for conservation. Encouragingly, however, a survey of visitors who attended live animal demonstrations at Brookfield Zoo demonstrated a high retention rate of educational messages six weeks after the show (Heinrich & Birney, 1992).

The renewed interest in global amphibian declines has led to a number of zoos providing prominent and eye-catching visitor interpretation on this topic to complement their live animal displays (Fig. 1). More research is needed on how effective such displays are in changing the ways people think and act about amphibian conservation. It would be interesting to know, for example, whether such displays are more – or less – effective when accompanied by live animals. For effective evaluation, it will also be important to compare the impact of such a display to an appropriate baseline. An interpretation display that results in only a marginal increase in visitor awareness may still be worthwhile if its overall impact remains higher than that achieved by similarly resourced initiatives within other media, such museums, natural history TV programmes and wildlife magazines. Only comparative studies will reveal the answers.

The Role of Zoos and Aquaria in Amphibian Captive Breeding and Conservation

Zoos as Conservation Centres. There may be about 10,000 animal collections worldwide that can be regarded as ‘zoos’. Of these, about 10% participate in national, regional or international federations that aim to work towards common goals. Globally, about 600 million people per year visit zoos that belong to organized networks, perhaps representing about 10% of the entire world population (IUDZG/CBSG, 1993; WAZA, 2005). However, those areas of the world that support the highest levels of biodiversity – and this includes areas of high amphibian diversity

– have relatively few zoos (Magin et al., 1994). Indeed, as zoos in developing countries are often poorly developed and underfunded, most co-ordinated conservation breeding programmes are operated by better funded institutions in North America, Europe or Australia.

Since the 19th century the role of zoos has evolved considerably, and will continue to do so in the future. Early zoos were primarily for public entertainment or recreation with the emphasis on displaying a wide variety of animal life, often under spartan conditions, and with little prominence given to breeding animals in captivity. In the 20th century animal collections moved more towards displaying animals in the form of a 'living museum', with greater emphasis on cooperative species management and ecological issues based around more naturalistic exhibits. Maintaining captive populations as a 'safety net against extinction' and for 'reintroduction to the wild' became mantras within the zoo community during the latter decades of the 20th century. Indeed, the IUCN policy statement on captive breeding in 1987 highlighted the importance of captive breeding as a tool for the conservation of endangered species, and acted as a catalyst for zoos to develop their individual missions in this direction. However, with the emergence of conservation biology as a scientific discipline in its own right, the value of the safety net principle propounded by zoos has been increasingly questioned (e.g. Snyder et al., 1996). Many species for which captive breeding programmes were set up were not high priority threatened species, and there was relatively little attention paid to evaluating whether or not captive breeding was an appropriate tool for the species concerned. Equally, many captive breeding programmes generated animals that were never likely to be released into the wild for logistical, financial or political reasons, and indeed, there was little point in trying to do so unless the threats that had led to the original decline of the species were identified and neutralized. Equally, the justification of ex situ conservation rather than in situ conservation has come under increasing scrutiny: analyses have shown that in situ conservation may be more cost-effective than ex situ conservation involving captive populations, at least for certain species (Balmford et al., 1995). Although zoos may therefore have promoted the idea of captive breeding more to justify their own existence than as a proactive tool for conservation, recent years have seen a growing acknowledgment within the zoo community that they must get more involved with field-based conservation if they are to be significant players within the conservation arena. Consequently, zoos are now adopting a more holistic approach by becoming ‘conservation centres’ focused on wider biodiversity issues at the global level (WAZA, 2005). As Miller et al. (2004) point out, zoos today must do more than just pay lip service to conservation by carrying out a few green activities – conservation must be the whole raison d’etre for their existence with a mission statement that is accountable. They pose eight questions that might help evaluate the conservation mission of a collection-based institution:

(1) Does conservation define policy decisions?
(2) Does the institution have significant organisational funding for conservation activites? Only a handful of collection-based institutions commit more than 5% of their operating budget to conservation, and 10% may be insufficient for a mission.
(3) Does the institution have a functional conservation department that performs conservation science and/or increases the capacity of others to do conservation?
(4) Does the institute advocate for conservation?
(5) Do the institution’s conservation education programmes effectively target children and adults?
(6) Does the institution contribute directly to habitat protection, both internationally and locally?
(7) Do the institution’s exhibits promote conservation efforts?
(8) Do the institution’s internal operating policies protect the environment?

As Miller et al. (2004) emphasize, there are currently dramatic differences between zoos in their commitment to conservation, and these eight questions may provide a starting point for such institutions to harness expertise and resources more effectively in pursuit of their goal of becoming conservation centres with real impact and influence.

So where does amphibian conservation fit in the evolving role of zoos today? In 1993 it was estimated that the world’s zoos held about 1 million vertebrate animals, of which some 25,000 were amphibians (IUDZG/CBSG, 1993). Perhaps not surprisingly, this is the lowest representation of any vertebrate class. Do small, cryptic animals such as amphibians therefore deserve a lower priority within zoo collection planning?

Smaller animals are usually cheaper to maintain in captivity and achieve higher rates of population growth than large animals. However, larger animals have longer generation times and lose heterozygosity more slowly, and can therefore be maintained as smaller populations within zoological collections. Consequently both body size and generation length are important considerations in selecting species for cost-effective captive breeding programmes (Balmford et al., 1996). Nevertheless, there remains a strong bias within zoos for large vertebrates, and there is little evidence that captive breeding programmes are targeting species that breed well in captivity, are cheaper to keep or easy to reintroduce to the wild. This may be because zoo managers perceive that the public want to see large charismatic vertebrates when they visit their collections. An analysis of visitor preferences at the 10 main exhibits at London Zoo found no evidence for such a trend. In fact, the reptile house and aquarium – where amphibians have been traditionally displayed – were among the three most popular exhibits in the zoo. Further analyses at two other British zoos did find a positive relationship between animal body size and popularity of the exhibit with visitors, but when the cost of the exhibit was taken into account, this relationship disappeared, i.e. exhibits of large animals are no more profitable than those of small animals (Balmford, 2000). On the basis of these analyses, it may well be possible for zoos to refocus their exhibits towards smaller taxa – including amphibians – without compromising income streams or visitor preferences.

A more recent analysis showed that there has been a marked increase in the number of threatened species held in zoos as part of co-ordinated breeding programmes over the past ten years (Leader-Williams et al. in press). However, a disproportionate focus on large mammals, birds and reptiles was maintained, and an extreme under-representation among amphibians, fishes, insects and crustaceans.

Of the 129 captive breeding and reintroduction projects analysed by Beck et al. (1994), 76 (59%) involved zoo bred animals, suggesting that – at least over the period of their review – that only one in five zoos in the developed world had been actively involved in reintroduction. Of the 31 483 captive bred reptiles and amphibians that were identified as having been reintroduced by the same study, a minimum of 10 620 animals originated from zoo-based projects. As is the case with other vertebrate classes then, much of the reintroduction effort carried out for reptiles and amphibians is carried out by national, regional or local conservation organisations rather than zoos.

Co-operative population management programmes. There are national, regional and international associations for zoos and aquaria that promote conservation, education, research and animal husbandry programmes through their members. Linkages exist between these organisations so that – for example – national population management programmes feed into a wider regional and international programme where appropriate. Indeed, the organisational infrastructure underpinning the population management and conservation programmes of zoos and aquaria is complex and contains a diversity of acronyms. The respective regional organisations for Europe and North America are the European Association of Zoos and Aquaria (EAZA) and the American Zoo and Aquarium Association (AZA). These regional organisations oversee a variety of conservation management programmes, and members may be affiliated to the World Association of Zoos and Aquaria (WAZA). Within AZA, the Species Survival Plan Program (SSP) is designed to ensure the survival of certain species of conservation interest within the collections of association members. Essentially, SSPs are co-operative population management programmes that aim to maintain healthy and sustainable populations that are genetically and demographically stable. This is achieved through the management of a studbook that contains records of lineages, natality, mortality, and movements between collections for all individuals within the managed population. SSPs are also involved with research, education and in situ field-based projects. There are currently 106 SSPs covering 161 species in operation, but these contain just two amphibian species – the Puerto Rican crested toad and the Wyoming toad. The Puerto Rican crested toad was the first amphibian to be considered for a SSP, which now involves some 20 zoos and aquaria in North America (Johnson, 1999). In addition to SSPs, Population Management Plans (PMPs) are run to maintain stable and sustainable captive populations of a broad range of species for display and conservation purposes. PMPs are designed for species that do not require such intensive captive management as those species within SSPs, but follow the same studbook population management protocols. There are some 282 PMPs currently in operation under the AZA umbrella, of which seven are for amphibians.

In Europe, EAZA operates similar population management programmes for certain species under the EEP and ESB schemes. There are currently 151 and 140

EEPs and ESBs respectively, but none of these include any amphibian projects, although several are currently under consideration (Gibson, pers. comm.).

Within the regional zoo and aquaria associations Taxon Advisory Groups (TAGs) provide advice on regional collection planning, the selection and management of species within conservation programmes, and animal husbandry issues. In AZA there is a specific TAG for amphibians, while within EAZA the relevant TAG covers both amphibians and reptiles.

Although zoo organisations now have a sound infrastructure to optimise captive breeding and population management programmes, this infrastructure has been largely built around the needs of mammals and birds. Only comparatively recently have less charismatic taxa, i.e. amphibians, reptiles, fishes and invertebrates been embraced within these co-operative management programmes. However, some of the protocols used to manage captive populations of mammals and birds may not be applicable to amphibians. Certainly, the current software used by zoos for managing studbooks and breeding programmes relies on the individual identification of animals. In contrast, amphibians are often maintained in colonies without such individual identification. In herpetological programmes SSPs and PMPs should not be viewed as conservation efforts in their own right, and perhaps too much emphasis is placed on these and their associated studbook management by zoos (Card et al., 1998). Unlike large vertebrates, viable populations of amphibians can be maintained within single collections, thereby negating the need for a co-ordinated breeding programme involving several partners and a studbook. The apparently successful reintroduction of European treefrogs in Latvia, for example, stemmed from the release of some 4000 froglets that were all bred at a single institution - Riga Zoo - between 1988 and 1992 (Zvirgzds et al., 1995; Zvirgzds, 1998). Likewise, the Mallorcan midwife toad – arguably the most successful captive breeding and reintroduction programmes of any amphibian species – is not managed under a EEP. The relatively small number of zoos involved - and the fact that each could maintain a viable population on their own – means that the toads can be managed most effectively as a component of a wider recovery programme under the auspices of the Mallorcan conservation authorities, rather than under the umbrella of a EEP scheme. Within co-ordinated species management programmes, different management infrastructures may be needed for different taxa. The findings of the Global Amphibian Assessment should prompt a timely review of how amphibian populations are managed within the zoo community.

The Conservation Breeding Specialist Group (CBSG). The Captive Breeding Specialist Group of IUCN's Species Survival Commission was formed in 1979 to provide liaison between in situ and ex situ conservation programmes and assist co-operation between organisations in the development of breeding programmes. It achieves this by running structured workshops around the world that bring together the various stakeholders involved with conservation projects with a view to resolving management plan and risk assessment issues. Increasing emphasis on the management of wild populations led the group to change its name from 'Captive Breeding…' to 'Conservation Breeding…' in 1994, and today about half of the workshops it runs focus on wild populations (Byers & Seal, 2003). There are two principal workshop programmes run by CBSG. 'Conservation Assessment and Management Plan' (CAMP) workshops focus on rapid assessment of threats to specific taxa – or the taxa of specific regions – using the IUCN Red List system. Recommendations emerge from the workshops to how address the threats and assign priorities for action. Over 70 CAMP workshops have been undertaken since 1991 (Byers & Seal, 2003), and these include three that have had a specific amphibian focus and have published reports available – Amphibians of India CAMP, Madagascar Reptile and Amphibian CAMP and Southern African Frog CAMP. Out of the 101 species assessed in the Indian amphibian CAMP, captive breeding was recommended as a component in the programmes for 71 species. In contrast, no South African or Malagasy frogs were recommended for captive breeding in their respective programmes (Harrison et al., 2001; IUCN/CBSG, 1997, 2002). More recent assessments made as part of the Global Amphibian Assessment have also included recommendations for captive breeding.

'Population and Habitat Viability Analysis' (PHVA) workshops integrate data on population demography, genetics and ecology of individual species with anthropogenic threats and employ stochastic computer modelling to make predictions about population trends and extinction risk under different scenarios. Reports are available for 75 PHVA workshops, and these include three amphibian species – the Houston toad, Wyoming toad and Puerto Rican crested toad. Conservation programmes for all three species contain a captive breeding component. The cryptic lifestyle of many amphibian species means that the population parameters that are required for population models are not easy to measure. Moreover, there is debate within the literature concerning the value of such population viability modelling exercises, particularly for endangered species in which the required demographic and environmental parameters are poorly known (e.g. Brook et al., 2000; Coulson et al., 2001; Reed et al., 2002).

The Role of the Private Sector

The role of private individuals that keep and breed amphibians as a hobby in amphibian conservation is opaque. As Backner (1994) points out, the private sector embraces a diversity of interests, educational backgrounds and animal keeping facilities. The reptile and amphibian pet business has grown from being a minority and rather eccentric activity to a multi-million dollar industry over recent decades. Although the growth in interest in snakes and lizards has certainly not been matched by that in amphibians, there are probably more amphibians – and more amphibian species – being kept in private households than ever before. Debates over the implications of this rapid growth of interest for conservation are frequently the subject of letters and articles in local and national herpetological newsletters. The private sector – often supported by the pet industry – argue that increased interest in amphibians can only be a positive thing for the species concerned; that captive breeding means that fewer wild populations will be exploited; and that when wild animals are collected for the trade it can be done on a sustainable basis and may benefit local communities in poor countries economically. At the other end of the spectrum, some conservationists argue that displaying amphibians and reptiles in captivity fuels the trade rather than raising awareness of their plight; that private breeding programmes do not contribute directly or indirectly to wider conservation problems; that there is no evidence that wild populations are being harvested on a sustainable basis; and that the main beneficiaries of the trade are western pet dealers rather than local communities. Sadly, there is a paucity of data to support the arguments on either side, and the truth is likely to vary considerably between species and regions. The debate is frequently muddied further by the animal welfare lobby, who – rightly or wrongly – object to the keeping of exotic animals in captivity as an ethical principle, but attempt to harness conservation arguments in support of their stance. The result is often a polarized debate with interest groups at both extremes arguing that they know what is best for conservation.

What is clear is that there is a wealth of expertise and resources within the private sector that has not been effectively harnessed for amphibian conservation. Resolving these controversial issues so that the private sector can be effectively utilized within conservation and captive breeding programmes will require some unorthodox and challenging initiatives that may meet resistance from scientists, zoo professionals and law enforcement officers (Backner, 1994). However, when the private sector has contributed to amphibian conservation it has invariably been through the medium of membership organisations rather than through initiatives by motivated individuals. The British Herpetological Society – an organisation whose members are predominantly non-professional herpetologists – has provided financial support for a number of conservation projects, including that of the natterjack toad at Marwell Zoo (Edgar, 1990) and the Mallorcan midwife toad at Jersey Zoo (Buley & Villavicencio, 2000). The same society has also provided infrastructural support for the axolotl recovery programme in Mexico (Griffiths et al., 2004). With several thousand members, the DGHT is one of the world's largest herpetological societies, and organises its activities through a series of special interest groups. The DGHT Anuran Specialist Group aims to establish self-sustaining populations of frogs in captivity and enlarge knowledge of taxonomy, behaviour, physiology, genetics and breeding. From 1989-1991, over 3900 individuals of 27 different species of dendrobatid and over 340 individuals of two mantella species were bred over multiple captive generations (Zimmermann & Zimmermann, 1994).

Conclusion – the new amphibian ark?

With some 32% of species threatened and perhaps up to 108 species already extinct (Stuart et al., 2004), the amphibian decline crisis presents new challenges for conservation biologists. For many species that face complex threats related to habitat loss, climate change and emerging infectious diseases the situation is likely to get worse before actions to address these issues can start to have impact. As Stuart et al. (2004) point out: 'for a species facing an "enigmatic decline", the only conservation option currently available is captive breeding'. This places conservation biologists in something of a dilemma. Should the amphibian ark give preference to those species likely to go extinct in the wild unless rescued by captivity? Or should it focus on those species that face less complex threats that have some chance of being neutralized, and consequently a realistic chance of reintroduction to the wild? In essence, the arguments boil down to moral issues versus ecological issues. Do we have a moral obligation to save species from extinction by whatever means, in the naïve hope that their habitats will some day be suitable enough to support them? Or do we have an ecological obligation to maintain intact communities and ecosystems?

Whatever the way forward, if captive breeding has a role to play in the future of amphibian conservation it will have to be done very differently to how it has been done in the past. There will need to be a move away from traditional, out-of-country multi-species facilities towards in-country, single species units with full quarantine and isolation infrastructure. Genetic screening and health monitoring will need to become integral parts of captive management, and the facilities will need to interface with the management of wild populations as closely as possible. There will need to be much better dissemination of research results from such projects – both to the public and to other researchers – to ensure that conservation actions maximise their impact. Achieving these goals will require a new breed of amphibian conservation biologist with a diversity of skills and knowledge. In addition to a sound understanding of the principles and techniques of captive population management, such technicians will also need to be effective field biologists. They will also need to be able to engage with local communities – as well as with the wider research and conservation communities – to ensure that projects can integrate capacity, expertise and knowledge as it emerges. Training and capacity building should therefore be a core component of future global amphibian conservation initiatives.

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References

Arntzen, J.W. & García-París, M. 1995. Morphological and allozyme studies of midwife toads (genus *Alytes*), including the description of two new taxa from Spain. Contributions to Zoology 65: 5-34

Backner, B.F. 1994. The future role of the private sector in breeding endangered species. In J.B. Murphy, K. Adler & J.T. Collins (eds.), Captive Management and Conservation of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Ithaca, New York. Contributions to Herpetology vol. 11, pp. 387-390.

Balmford, A. 2000. Separating fact from artifact in analyses of zoo visitor preferences. Conservation Biology 14: 1193-1195.

Balmford, A., Leader-Williams, N. & Green, M.J.B. 1995. Parks or arks: where to conserve threatened mammals? Biodiversity and Conservation 4: 595-607.

Balmford, A., Mace, G.M. & Leader-Williams, N. 1996. Designing the ark: setting priorities for captive breeding. Conservation Biology 10: 719-727.

Banks, C. 2002. A thirty-year history of Melbourne Zoo's herp department. Herpetological Review 33: 256-259.

Banks, C.B. &McCracken, H.E. 2002. Captive management and pathology of Sharp-snouted Torrent Frogs, *Taudactylus acutirostris*, at Melbourne and Taronga Zoos. In Nattras, A.E.O. (Ed.) Frogs in the Community. Brisbane: Queensland Frog Society Inc. Pp. 94-102

Banks, C.B., J. Birkett, S. Young, M. Vincent & T. Hawkes. 2003. Breeding and management of the Great Barred Frog, *Mixophyes fasciolatus*, at Melbourne Zoo. Herpetofauna 33:2-12.

Beck, B.B., Rapaport, L.G., Stanley Price, M.R. & Wilson, A.C. 1994. Reintroduction of captive-born animals. In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.). Creative Conservation: Interactive Management of Captive and Wild Animals. Chapman & Hall, London. Pp. 265-286.

Beebee, T.J.C. & Griffiths, R.A. 2005. The amphibian decline crisis: a watershed for conservation biology? Biological Conservation 125: 271-285.

Berger, L., Speare, R., Hines, H.B., Marantelli, G., Hyatt, A.D., McDonald, K.R., Skerratt, L.F., Olsen, V., Clarke, J.M., Gillespie, G., Mahony, M., Sheppard, N., Williams, C. & Tyler, M.J. 2004. Effect of season and temperature on mortality in amphibians due to chytridiomycosis. Australian Veterinary Journal 82: 434-439.

Bloxam, Q. M. C. & Tonge, S. J. 1994. Amphibians – suitable candidates for breeding-release programmes. Biodiversity and Conservation 4: 636-644.

Broad, G. 1996. Evaluation of informal education at Jersey Zoo. Research Department Report, Jersey Wildlife Preservation Trust.

Brook, B.W., O'Grady, J.J., Chapman, A.P., Burgman, M.A., Akçakaya, H.R. & Frankham, R. 2000. Predictive accuracy of population viability analysis in conservation biology. Nature 404: 385-387.

Buley, K.R. & García, G. 1997. The recovery programme for the Mallorcan midwife toad *Aytes muletensis*: an update. Dodo 33: 80-90.

Buley, K.R. & Gonzalez-Villavicencio, C. 2000. The Durrell Wildlife Conservation Trust and the Mallorcan midwife toad, *Alytes muletensis* – into the 21st century. Herpetological Bulletin 72: 17-20.

Bush, S. 1997. Vocal behavior of males and females in the Majorcan midwife toad. Journal of Herpetology 31: 251-257.

Byers, O. & Seal, U.S. 2003. The Conservation Breeding Specialist Group (CBSG): activities, core competencies and vision for the future. International Zoo Yearbook 38: 43-53.

Card, W.C., Roberts, D.T. & Odum, R.A. 1998. Does zoo herpetology have a future? Zoo Biology 17: 453-462.

Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63: 215-244.

Collins, J.P. & Storfer, A., 2003. Global amphibian declines: sorting the hypotheses. Diversity and Distributions 9, 89-98.

Coulson, T. et al. 2001. The use and abuse of population viability analysis. Trends in Ecology and Evolution 16: 219-221.

Cunningham, A.A. 1996. Disease risks of wildlife translocations. Conservation Biology 10: 349-353.

Daly, J.W., Garraffo, H.M., Hall, G.S.E. & Cover, J.F. 1997. Absence of skin alkaloids in captive-raised Madagascan mantelline frogs (*Mantella*) and sequestration of dietary alkaloids. Toxicon 35: 1131-1135.

Daszak, P., Cunningham, A.A. & Hyatt, A.D., 2003. Infectious disease and amphibian population declines. Diversity and Distributions 9, 141-150.

Denton, J.S., Hitchings, S.P., Beebee, T.J.C. & Gent, A. 1997. A recovery program for the natterjack toad (*Bufo calamita*) in Britain. Conservation Biology 11: 1329-1338.

Dodd, C.K. 2005. Population manipulations. Pp. 265-270 In: M.J. Lannoo (ed.), Declining Amphibians: The Conservation Status of United States Species. University of California Press, Berkeley, USA.

Dodd, C.K. & Seigel, R.A. 1991. Relocation, repatriation and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica 47: 336-350.

Dudgeon, D. & Lau, M.W.N. 1999. Romer's frog reintroduction into a degraded tropical landscape, Hong Kong, P.R. China. Re-introduction News 17: 10-11.

Edgar, P. 1990. A captive breeding and release programme for sand lizards and natterjack toads at Marwell Zoological Park: an appeal for sponsorship. British Herpetological Society Bulletin 31: 3-10.

Fa, J.E. & Clark, C.C.M. 1997. Dissecting a DESMAN: the JWPT/UKC Diploma in Endangered Species Management. Dodo 33: 137-144.

Fa, J.E., Clark, C.C.M. & Hicks, S.D.J. 1995. Training in zoo biology at the Jersey Wildlife Preservation Trust: a retrospective look and a glance at the future. Dodo 31: 28-40.

Fernandez, P.J 1996. A facility for captive propagation of Chiricahua leopard frogs (*Rana chiricahuensis*). Herpetoculture. 7-12. International Herpetological Symposium.

Gibson, R.C. & Buley, K.R. 2004. Maternal care and obligatory oophagy in *Leptodactylus fallax*: a new reproductive mode in frogs. Copeia 2004: 128-135.

Gilligan, D. M. & Frankham, R. (2003) Dynamics of genetic adaptation to captivity. Conservation Genetics 4: 189-197.

Griffith, B., Scott, J.M., Carpenter, J.W. & Reed, C. 1989. Translocation as a species conservation tool: status and strategy. Science 245: 477-480.

Griffiths, R.A., Graue, V., Bride, I.G. & McKay, J.E. 2004. Conservation of the axolotl (*Ambystoma mexicanum*) at Lake Xochimilco, Mexico. Herpetological Bulletin 89: 4-11.

Griffiths, R.A., Schley, L., Sharp, P.E., Dennis, J.L. & Román, A. 1998. Behavioural responses of Mallorcan midwife toad tadpoles to natural and unnatural predators. Animal Behaviour 55: 207-214.

Harding, K.A. 1993. Conservation and the case of the golden toad. British Herpetological Society Bulletin 44: 31-34.

Harrison, J.A., Burger, M., Minter, L.R., De Villiers, A.L., Baard, E.H.W., Scott, E., Bishop, P.T. & Ellis, S. 2001. Conservation Assessment and Management Plan for Southern African frogs. Final Report. IUCN/SSC, CBSG: Apple Valley, M.N.

Harwell, G. & Quinn, H. 1982. The Houston toad - problems associated with the captive propagation of amphibians. Proceedings of the Amererican Association of Zoo Veterinarians:1-2.

Heinrich, C.J. & Birney, B.A. 1992. Effects of live animal demonstrations on zoo visitors retention of information. Anthrozoos 5: 113-121.

Hutchins, M. 2003. Zoo and aquarium animal management and conservation: current trends and future challenges. International Zoo Yearbook 38: 14-28.

IUCN/CBSG. 1997. Amphibians of India. IUCN/SSC, CBSG: Apple Valley, M.N.

IUCN/CBSG. 2002. Evaluation et Plans de Gestion pour la Conservation (CAMP) de la Faune de Madagascar: Lémuriens, Autres Mammifères, Reptiles et Amphibiens, Poissons d'eau douce. IUCN/SSC, CBSG: Apple Valley, M.N.

IUDZG/CBSG. 1993. The World Zoo Conservation Strategy: the Role of Zoos and Aquaria of the World in Global Conservation. Chicago Zoological Society, Brookfield, Illinois.

Jehle, R., Arntzen, J.W., Burke, T., Krupa, A.T. & Hodl, W. 2001. The annual number of breeding adults and the effective population size of syntopic newts (*Triturus cristatus* and *T. marmoratus*). Molecular Ecology 10: 839-850.

Johnson, R.R. 1994. Model programs for reproduction and management: ex situ and in situ conservation of toads of the family Bufonidae. In Murphy, J.B., Adler, K. & Collins, J.T. (eds.), Captive Management and Conservation of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Ithaca, New York. Contributions to Herpetology vol. 11. Pp. 243-254.

Johnson, B. 1999. Recovery of the Puerto Rican crested toad. Endangered Species Bulletin 24: 8-9.

Jones, C.G. 2002. Reptiles and amphibians. In: Perrow, M.R. & Davy, A.J. (Eds.). Handbook of Ecological Restoration. Cambridge University Press, Cambridge, UK.Pp. 355-375.

Kiesecker, J.M., Blaustein, A.R. & Belden, L.K., 2001. Complex causes of amphibian decline. Nature 410, 681-684.

Kraaijeveld-Smit, F.J.L., Beebee, T.J.C., Griffiths R.A., Moore, R.D. & Schley, L. 2005. Low gene flow but high genetic diversity in the threatened Mallorcan midwife toad *Alytes muletensis*. Molecular Ecology 14: 3307-3315.

Kraaijeveld-Smit, F.J.L., Griffiths, R.A., Moore, R.D. & Beebee, T.J.C. 2006. Captive breeding and the fitness of reintroduced species: a test of the responses to predators in a threatened amphibian. Journal of Applied Ecology (in press).

Kuwabara, K., Suzuki, N., Wakabayashi, F., Ashikaga, H., Inoue, T. & Kobara, J. 1989. Breeding the Japanese giant salamander at Asa Zoological Park. International Zoo Yearbook, London 28: 22-31.

Leader-Williams, N, Balmford, A.P., Linkie, M., Mace, G.M., Smith, R.J., Stevenson, M., Walter, O., West, C.D. & Zimmerman, A. in press. Beyond the ark: conservation biologists' views of the achievements of zoos in conservation. Proceedings of the Zoological Society of London.

Lee, S., Zippel, K.C., Ramos,L. & Searle, J. The Kihansi spray toad (*Nectophrynoides asperginis*) captive propagation program at the Wildlife Conservation Society. International Zoo Yearbook (in press).

MacGregor, H. 1994. An evaluation of the educational value of a zoo reptile exhibit. MSc Dissertation, DICE, University of Kent, Canterbury, UK.

Magin, C.D., Johnson, T.H., Groombridge, B., Jenkins, M. & Smith, H. 1994. Species extinctions, endangerment and captive breeding. In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.). Creative Conservation: Interactive Management of Captive and Wild Animals. Chapman & Hall, London. Pp. 3-31.

Marcellini, D.L. & Jenssen, T.A. 1988. Visitor behavior in the Nacional Zoo's reptile house. Zoo Biology 7: 329-338.

Marcellini, D.L. & Murphy, J.B. 1998. Education in a zoological park or aquarium: an ontogeny of learning opportunities. Herpetologica 54: S12-S16.

Marsh, D. M. & Trenham, P. C. 2000. Metapopulation dynamics and amphibian conservation. Conservation Biology 15: 40-49.

Miller, B., Conway, C., Reading, R.P., Wemmer, C., Wildt, D., Kleiman, D., Monfort, S., Rabinowitz, A., Armstrong, B. & Hutchins, M. 2004. Evaluating the conservation mission of zoos, aquariums, botanical gardens, and natural history museums. Conservation Biology 18: 86-93.

Miller, T.J. 1985. Husbandry and breeding of the Puerto-Rican toad (*Peltophryne lemur*) with comments on its natural history. Zoo Biology 4: 281-286.

Moore R.D., Griffiths R.A. & Román A. 2004. Distribution of the Mallorcan midwife toad (*Alytes muletensis*) in relation to landscape topography and introduced predators. Biological Conservation 116: 327–332.

Nichols, D.K., Lamirande, E.W., Pessier, A.P. & Longcore, J.E. 2001. Experimental transmission of cutaneous chytridiomycosis in dendrobatid frogs. Journal of Wildlife Diseases 37: 1-11.

Parker, J.M. & Anderson, S.H. 2003. Habitat use and movements of repatriated Wyoming toads. Journal of Wildlife Management 67: 439-446.

Pavajeau, L. 2005. Captive breeding and release of amphibians. MSc Dissertation, DICE, University of Kent, Canterbury, UK.

Pechmann, J.H.K., Scott, D.E., Semlitsch, R.D., Caldwell, J.P., Vitt, L.J. & Gibbons, J.W. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253: 892-895.

Phillpot, P. 1996. Visitor viewing behaviour in the Gaherty reptile breeding centre. Dodo 32: 193-202.

Pounds, J.A. & Crump, M.L. 1994. Amphibian declines and climate disturbance: the case of the golden toad and the harlequin frog. Conservation Biology 8: 72-85.

Pounds, J.A., Fogden, M.P.L. & Campbell, J.H., 1999. Biological response to climate change on a tropical mountain. Nature 398: 611-615.

Poynton, S.L. & Whitaker, B.R. 1994. Protozoa in poison dart frogs (Dendrobatidae) – clinical assessment and identification. Journal of Zoo and Wildlife Medicine 25: 29-39.

Preece, D.J. 1998. The captive management and breeding of poison-dart frogs, family Dendrobatidae, at Jersey Wildlife Preservation Trust. Dodo 34: 103-114.

Quinn, H., Peterson, K., Mays, S., Freed, P. & Neitman, K. 1989. Captive propagation/release and relocation program of the endangered Houston toad, *Bufo houstonensis*. Proceedings of the 1989 AAZPA National Conference. Wheeling, WV: AAZPA.

Reed, J.M., Mills, S., Dunning, J.B., Menges, E.S., McKelvey, K.S., Frye, R., Beissinger, S.R., Anstett, M.-C. & Miller, P. 2002. Emerging issues in population viability analysis. Conservation Biology 16: 7-19.

Roca, V., García, G., Carbonell, E., Sánchez-Acedo, C. & Del Cacho, E. 1998. Parasites and conservation of *Alytes muletensis* (Sanchiz et Adrover, 1977) (Anura: Discoglossidae). Revista Espanola de Herpetologica 12: 91-95.

Rowe, G. & Beebee, T.J.C. 2004. Reconciling genetic and demographic estimators of effective population size in the anuran amphibian *Bufo calamita*. Conservation Genetics 5: 287-298.

Säisä, M., Koljonen, M.-L. & Tähtinen, J. 2003. Genetic changes in Atlantic salmon stocks since historical times and the effective population size of a long-term captive breeding programme. Conservation Genetics 4: 613-627.

Schmidt, B.R. 2003. Count data, detection probabilities, and the demography, dynamics, distribution, and decline of amphibians. Comptes Rendues Biologie 326: 119-124.

Schmidt, B.R. 2004. Declining amphibian populations: the pitfalls of count data in the study of diversity, distributions, dynamics and demography. Herpetological Journal.14: 167-174.

Seigel, R.A. & Dodd, C.K. 2002. Translocations of amphibians: proven management method or experimental technique? Conservation Biology 16: 552-554.

Serbinova, I.A., Shubravy, O.I., Uteshev, V.K., Agasian, A.L. & Goncharov, B.F. 1990. Keeping, breeding in captivity and establishment of new natural populations of *Pelobates syriacus*. Zookultura Amfibii. 82-89. Moscow.

Shepherdson, D. 1994. The role of environmental enrichment in the captive breeding and reintroduction of endangered species. In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.). Creative Conservation: Interactive Management of Captive and Wild Animals. Chapman & Hall, London. Pp. 165-177.

Snyder, N.F.R., Derrickson, S.R., Beissinger, S.R., Wiley, J.W., Smith, T.B., Toone, W.D. & Miller, B. 1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10: 338-348.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischmann, D.L. & Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306: 1783-1786.

Taylor, S.K., Williams, E.S., Pier, A.C., Mills, K.W. & Bock, M.D. 1999a. Mucormycotic dermatitis in captive adult Wyoming toads. Journal of Wildlife Diseases 35: 70-74.

Taylor, S.K., Williams, E.S., Thorne, E.T., Mills, K.W., Withers, D.I. & Pier, A.C. 1999b. Causes of mortality of the Wyoming toad. Journal of Wildlife Diseases 35: 49-57.

Tudge, C. 1991. Last Animals at the Zoo. Oxford University Press, Oxford, UK.

WAZA. 2005. Building a Future for Wildlife – The World Zoo and Aquarium Conservation Strategy. WAZA, Bern, Switzerland.

Wiese, R.J. & Hutchins, M. 1994. The role of zoos and aquariums in amphibian and reptile conservation. In Murphy, J.B., Adler, K. & Collins, J.T. (eds.), Captive Management and Conservation of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Ithaca, New York. Contributions to Herpetology vol. 11. Pp. 37-45.

Wilson, A.C. & Stanley Price, M.R. 1994. Reintroduction as a reason for captive breeding. In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.). Creative Conservation: Interactive Management of Captive and Wild Animals. Chapman & Hall, London. Pp. 243-264.

Woodworth, L. M., Montgomery, M. E., Briscoe, D. A. & Frankham, R. 2002. Rapid genetic deterioration in captive populations: causes and conservation implications. Conservation Genetics 3: 277-288.

Zimmermann, H. and Zimmermann, E. 1985. Care and rearing of *Dendrobates quinquevittatus* and *Dendrobates reticulatus*. Nordisk Herpetologisk Forening. 28:76-90.

Zimmermann, E. & Zimmermann, H.1994. Reproductive strategies, breeding, and conservation of tropical frogs: dart-poison frogs and Malagasy poison frogs. In Murphy, J.B., Adler, K. & Collins, J.T. (eds.), Captive Management and Conservation of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Ithaca, New York. Contributions to Herpetology vol. 11. Pp. 255-266.

Zvirgzds, J. 1998. Treefrog reintroduction project in Latvia. Froglog 27: 2-3.

Zvirgzds, J. et al. 1995. Reintroductions of the European tree frog (*Hyla arborea*) in Latvia. Memoranda Soc. Fauna Flora Fennica 71: 139-142.

Table 1. List of species that have been used in captive breeding programmes for conservation purposes (i.e. potential reintroduction, conservation research or conservation education), but which have not been reintroduced to the wild. Data have been collated from the Global Amphibian Assessment, Amphibiaweb, other websites and published sources (modified from Pavajeau, 2005).

Scientific name	Common name	IUCN Red List Category	Area of origin
ANURA			
Atelopus angelito	no common name	CR	South America
Atelopus zeteki	Panamanian golden frog	CR	Central America
Dendrobates auratus	green poison frog	LC	North and Central America
Dendrobates azureus	blue dart-poison frog	VU	South America
Dendrobates leucomelas	yellow headed poison frog	LC	South America
Dendrobates reticulatus	reticulated poison dart frog	LC	South America
Dyscophus antongilii	tomato frog	NT	Madagascar
Hoplobatrachus rugulosus	Chinese edible frog	LC	Eastern Asia
Hoplobatrachus tigerinus	Indian bullfrog	LC	Southern Asia
Leiopelma archeyi	Archey's frog	CR	New Zealand
Litoria adelaidensis	slender tree frog	EN	Australia
Litoria raniformis	growling grass or southern bell frog	EN	Australia
Mixophyes balbus	silver-eyed barred frog	VU	Australia
Mixophyes fasciolatus	great barred frog	LC	Australia
Mixophyes fleayi	Fleay's barred-frog	EN	Australia
Mantella aurantiaca	golden mantella	CR	Madagascar
Mantella cowanii	Cowan's mantella	CR	Madagascar
Mantella expectata	blue-legged mantella	CR	Madagascar
Mantella laevigata	climbing mantella	NT	Madagascar
Mantella madagascariensis	Madagascan mantella	VU	Madagascar
Mantella pulchra	beautiful mantella	VU	Madagascar
Mantella viridis	green mantella	CR	Madagascar
Megophrys nasuta	Borneo horned frog	LC	SE Asia
Philautus alto	no common name	EN	Sri Lanka
Philautus asankai	no common name	EN	Sri Lanka
Philautus caerulensis	no common name	EN	Sri Lanka
Philautus fulvus	no common name	EN	Sri Lanka
Philautus silus	no common name	EN	Sri Lanka
Philautus simba	no common name	CR	Sri Lanka
Philautus sordidus	no common name	NT	Sri Lanka
Philautus viridis	no common name	EN	Sri Lanka
Philautus zorro	no common name	EN	Sri Lanka
Philoria frosti	baw baw frog	CR	Australia
Phyllobates terribilis	golden poison dart frog	EN	South America
Phyllomedusa lemur	lemur leaf frog	EN	Central America
Rana chensinensis	Asian grass frog	LC	Eastern Asia
Theloderma corticale	no common name	DD	SE Asia
CAUDATA			
Andrias japonicus	Japanese giant salamander	NT	Japan
Eurycea neotenes	Texas aquifer salamanders	VU	North America

Eurycea rathbuni	Texas aquifer salamanders	VU	North America
Eurycea sosorum	Texas aquifer salamanders	VU	North America
Hynobius leechii	no common name	LC	SE Asia
Pachyhynobius shangchengensis	no common name	VU	Eastern Asia
Pachytriton brevipes	black spotted stout newt	LC	Eastern Asia
Pachytriton labiatus	spotless stout newt	LC	Eastern Asia
Paramesotriton deloustali	Tam Dao salamander	VU	SE Asia
Ranodon sibiricus	Central Asian salamander	EN	Central Asia
Tylototriton kweichowensis	red tailed knobby newt	VU	Eastern Asia
Tylototriton shanjing	emperor newt	NT	Eastern Asia
Tylototriton taliangensis	Taliang knobby newt	NT	Eastern Asia
Tylototriton verrucosus	Himalayan salamander	LC	SE Asia

Table 2. List of species that have been used in captive breeding programmes and which have been reintroduced to the wild. Data have been collated from the Global Amphibian Assessment, Amphibiaweb, other websites and published sources (modified from Pavajeau, 2005).

Scientific name	Common name	IUCN Red List Category	Area of origin
ANURA			
Alytes muletensis	Mallorcan midwife toad	VU	Mallorca
Bufo baxteri	Wyoming toad	EN	North America
Bufo calamita	natterjack toad	LC	Europe
Bufo houstonensis	Houston toad	EN	North America
Chirixalus romeri	Romer's treefrog	EN	Eastern Asia
Hyla arborea	European Treefrog	NT	Europe
Litoria aurea	green and golden bell frog	VU	Australia
Litoria spenceri	Spencer's river tree frog	CR	Australia
Leiopelma pakeka	Maud Island frog	VU	New Zealand
Leptodactylus fallax	mountain chicken	CR	Caribbean Islands
Nectophrynoides asperginis	Kihansi spray toad	CR	Africa
Pelobates syriacus	Eastern spadefoot	LC	Europe, Middle East
Bufo lemur	Puerto Rican crested toad	CR	Puerto Rica
Rana chiricahuensis	Chiricahua leopard frog	VU	North America
Rana dalmatina	Agile frog	LC	Europe
Rana sevosa	Mississippi gopher frog	CR	North America
Rana subaquavocalis	Ramsey canyon leopard frog	CR	North America
Rana tarahumarae	Tarahumara frog	VU	North America
CAUDATA			
Ambystoma mexicanum	Mexican Axolotl	VU	North America
Cryptobranchus alleganiensis	Ozark Hellbender	NT	North America
Echinotriton chinhaiensis	Chinhai spiny newt	CE	Eastern Asia
Taudactylus acutirostris	sharp snouted day frog	CR	Australia
Triturus vittatus ophryticus	Banded newt	NT	Western Asia

Table 3. Examples of conservation research within captive breeding programmes for amphibians. Information has been obtained from the Global Amphibian Assessment and Web of Science.

A: Husbandry protocols
B: Nutrition
C: Genetics
D: Reproduction
E: Health monitoring/Veterinary care
F: Taxonomy
G: Capture/handling/monitoring methods
H: Reintroduction methodologies

Species	A	B	C	D	E	F	G	H	Source(s)
Alytes muletensis Mallorcan midwife toad	y		y	y	y	y			Arntzen & García-París (1995); Bush (1997); Buley & Garcia (1997); Roca et al. (1998); Griffiths et al. (1998); Buley & Gonzalez-Villavicencio (2000); Kraaijeveld-Smit et al. (2005)
Bufo baxteri Wyoming toad	y			y	y		y		Taylor et al. (1999a) Taylor et al. (1999b) Parker & Anderson (2003)
Bufo lemur Puerto Rican crested toad	y		y	y	y			y	Miller (1985) Johnson (1995, 1999)
Bufo houstonensis Houston toad	y				y			y	Harwell & Quinn (1982); Quinn et al. (1989)
Nectophrynoides asperginis Kihansi spray toad	y								Lee et al. (in press)
Leptodactylus fallax Mountain chicken	y			y					Gibson & Buley (2004)
Dendrobates auratus Green poison frog	y			y	y	y			Poynton & Whitaker (1994), Preece (1998), Nichols et al. (2001)
Dendrobates reticulatus Reticulated poison dart frog	y					y			Zimmermann & Zimmermann (1985,1994)
Mantella aurantiaca Golden mantella	y	y							Daly et al. (1997)
Hyla arborea European treefrog	y							y	Zvirgzds et al. (1995)
Pelobates syriacus Eastern spadefoot toad	y							y	Serbinova et al. (1990)
Rana chiricahuensis Chiricahua leopard frog	y								Fernandez (1996)
Andrias japonicus Japanese giant salamander	y								Kuwabara et al. (1989)
Chirixalus romeri Romer's treefrog	y							y	Dudgeon & Lau (1999)
Taudactylus acutirostris Sharp-snouted Torrent Frogs	y				y				Banks & McCracken (2002)
Mixophyes fasciolatus Great Barred Frog	y				y				Banks et al. (2003); Berger et al. (2004)

Figure 1. Public interpretation poster for the Southern Corroboree Frog conservation project, Melbourne Zoo (C. Banks).

Chapter 8

Reintroductions

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Griffiths, R.A., McKay, J., Tuberville, T. and K. Buhlmann

8.1 Introduction

Reintroduction of animals to the wild has frequently been promoted as the primary reason for breeding animals in captivity. However, captive breeding may contribute to conservation through actions that do not involve reintroduction (e.g. education, research) and reintroductions do not necessarily involve a captive component. Indeed, for many amphibian species, reintroductions may be achieved more efficiently, more safely and more cost-effectively if they do not involve a captive breeding component. Simple translocation of spawn or tadpoles, for example, can be an effective tool in species recovery. Where high levels of spawn or tadpole mortality are prevalent, head-starting tadpoles by raising them beyond the stages at which they are vulnerable to competitors, predators or other threats may also be preferable to captive breeding. Nevertheless, there are many issues that need to be carefully considered and addressed when a reintroduction is planned or carried out. The IUCN (1998) guidelines for reintroductions provide a framework for the protocols to be followed for amphibians, but may need modifying in view of species-specific requirements or linkages to other themes within the ACAP.

Many species are likely to recover on their own following mitigation of the threats coupled with habitat management, restoration or creation. Indeed, natural recolonization is likely to be more effective in terms of establishing viable populations, as well as logistics and costs. If natural recolonization is not possible because the restored habitat is isolated, consideration needs to be given to whether the area can support a viable population (or metapopulation) even if a reintroduction takes place. Reintroduction should therefore only be considered as an option where these mechanisms are deemed insufficient for ensuring species recovery on their own.

Whether or not they involve captive breeding, reintroduction programmes for amphibians are at an early stage of development, and it will be many years before we can make unqualified judgements concerning their effectiveness as a tool for conservation. Certainly more science is needed, but given the current biodiversity crisis, we cannot wait for all the necessary hypotheses to be rigorously tested before acting. Adaptive management – which relies on continuous review and refinement of programme protocols based on prior experience - will therefore always be an integral part of amphibian reintroduction programmes, and of conservation programmes in general.

8.2 Selecting Species for Reintroduction

Although a large number of species are recommended for reintroduction within the GAA, the selection of these species appears to be rather arbitrary and not based on objective criteria. There appears to be variation between regions in the tendency to recommend species for reintroduction, and this may reflect regional variation in expertise and personal interests rather than real needs for reintroduction. It is therefore essential that species are carefully appraised for their suitability for reintroduction.

The following criteria provide guidance for evaluating whether a species is suitable for reintroduction.

8.2.1 Status and distribution of the species

Without this information, it is difficult to make any objective recommendations for conservation or assess whether reintroduction is appropriate. Priorities for reintroduction should focus on globally threatened species, although locally threatened species may also be considered when they are of local political or cultural importance.

8.2.2 Reversibility of threats

The most successful animal reintroductions have usually involved those species that have threats that are easily neutralized (Griffith et al. 1989; Caughley 1994; Wilson & Stanley Price 1994). Threats that are more likely to be reversible are often those associated with direct persecution, pollution and those that can be realistically addressed using legal, political or cultural processes that are enforceable. It is often easier to reverse threats in clearly delimited geographical areas, such as islands, than it is in habitats that grade into each other. One problem facing amphibians is that the threats that they face are complex, often synergistic, and not easily reversed (Beebee & Griffiths, 2005). The reversibility of threats should therefore influence which species are considered for reintroduction programmes. Reversing localised agents of decline – such as introductions of fish or other predators – is likely to be more feasible than reversing global threats – such as climate change and increased UV-B.

8.2.3 Life history

Species in which certain life stages can be safely collected and translocated without detriment to the donor population will be most suitable for reintroductions. Such species will usually be those that have high fecundity and robust eggs, larvae or metamorphs that can be transported easily. Donor populations of species that display clear density dependence in larval development and survival are less likely to be impacted by the extraction of animals for translocation than populations that display other forms of population regulation.

8.2.4 Geographical priorities

Geographical priorities may be associated with priority areas for conservation, or areas where the political or logistic support is likely to increase the chances of success of a reintroduction. Most reintroductions carried out to date have been in temperate areas, rather than in those areas that support high levels of amphibian diversity. Careful consideration therefore needs to be given to balancing priorities between those geographical regions that are low in biodiversity but rich in expertise and infrastructure, and those areas poor in expertise and infrastructure but rich in biodiversity.

8.2.5 Taxonomic priorities

Monotypic genera or families, members of ancient lineages or taxa that are otherwise poorly represented in conservation programmes may be considered a priority in some circumstances. Where expertise and knowledge has been previously gained on a widespread or non-declining species, it may be cost-effective to consider closely related, threatened species for reintroduction as these may benefit from the existing knowledge base.

8.2.6 Wider biodiversity considerations

When a species is part of an ecological community or natural system that is of wider biodiversity interest, it may be considered a priority. Such species may play an important role in maintaining community structure and thereby influence other aspects of biodiversity.

8.3 Actions to Execute a Reintroduction

8.3.1 Publicity, public relations and information

These will be achieved by timely press releases, information leaflets, website information, T-shirts, post cards etc. In some cases it may be possible to develop nature tourism and possibly other economic incentives based on the species concerned. These actions should mobilize public support and consolidate political – and possibly financial – backing for the project.

8.3.2 Pre-release assessment of the wild populations

The status and distribution of the species will be assessed by a combination of interrogation of existing sources of information (e.g. GAA, local atlases etc.) and field survey. Refinement of existing survey methodologies may be required as an adjunct research activity to allow this. Priority species will be those that have undergone clear contractions in historical range, and which would be unable to re-establish functional populations (or metapopulations) within that range without reintroduction. Introductions to areas outside the historical range will usually be discouraged, although climate change data may suggest that unsuitable areas outside the natural range may become suitable sometime in the future. Equally, restocking (or supplementing) existing populations carries disease and genetic risks (see below) and should not be considered unless numbers have fallen below those required for a minimum viable population and the associated risks have been assessed.

8.3.3 Applied ecological research on life history and habitat requirements

Basic population demographic data on the species will be gathered if these parameters are not already known, as these will be required for population viability analysis and for informing decisions about which stages of the life cycle should be used for the reintroductions.

Similarly, habitat requirements will be determined so that habitat management, restoration and creation can be carried out in a way that will maximise the chances of the reintroduction succeeding (see below).

8.3.4 Threat mitigation, habitat management, restoration and creation

The threats leading to the decline or extinction of the species will be evaluated and neutralized following the protocol described by Caughley (1994). It is unlikely that some important threats to amphibians (e.g. climate change, UV-B etc.) can be neutralized, at least in the short to medium term. In such cases, reintroduction is unlikely to be a sensible option.

Following the assessment of habitat requirements, potential reintroduction sites will be evaluated for management requirements. The programme of habitat management will involve maintaining or enhancing existing areas, restoring areas that still exist but have become unsuitable and creation of new habitat where appropriate (or a combination thereof).

8.3.5 Population viability analysis, release protocols and strategic recovery plan development

Population and Habitat Viability Analysis (PHVA) may assist in determining targets for minimum viable populations, habitat requirements, and the time frames required to establish them (Akcakaya et al. 2004). These targets should then be embraced within a staged planning process, with interim milestones if necessary to monitor progress as the project develops. Knowledge of the life history of the species should be used to determine appropriate targets and time frames for success. EU legislation requires member states to maintain - or restore to - 'favourable conservation status' those species of community interest, and this is being used as a generic target in many species recovery programmes (although explicit definitions of this term may vary from species to species, and region to region).

The reintroductions will involve the release of eggs, larvae and/or metamorphs, as previous reintroduction programmes have shown that using these stages is most likely to lead to success. However, further research is needed on release protocols, (e.g. the relative proportions of the different stages, 'soft' vs. 'hard' releases, trade-offs of captive vs. wild stock, applicability of headstarting technologies). The reintroductions will therefore serve as ecological experiments for testing hypotheses concerning these issues, and protocols will be refined accordingly.

An appropriate organisational infrastructure needs to be established to ensure the success of the programme. This will invariably require the co-operation of a wide spectrum of stakeholders ranging from local communities to government officials. There may be legal obstacles associated with the release of organisms into the wild that need to be overcome. Effective lines of communication need to be established, language barriers overcome and transparent mechanisms for resolving differences of opinions established.

8.3.6 Risk analysis

The movement of living organisms from one place to another carries various risks. These risks may be genetic, ecological or socio-economic. Genetic risks are associated with the release of maladapted animals into an area. Donor populations will be screened for any potential problems associated will possible maladaptations or inbreeding. This will be combined with a landscape level analysis of the release site to ensure that the released population will not suffer from any genetic problems as a result of habitat isolation in the future. There may also be concern over the release of animals whose taxonomic relationships are unresolved. Linkage with the Systematics Theme Working Group to ACAP will be maintained to resolve any issues in this area.

Ecological risks embrace issues associated with the inadvertent transmission of disease or other organisms. Apparently benign organisms may have unforeseen impacts on food chains when transmitted to new environments. Protocols will therefore be in place to minimise the risk of transmission of propagules of potentially invasive species. Comprehensive health screening will be carried out on (1) animals from the donor population (captive or wild); (2) all amphibian species present at the release site. The protocols will follow those laid down by the Disease Working Group to ACAP. Socio-economic risks are associated with impacts on the livelihoods of local people. If the reintroduction results in the exclusion of people from traditional areas or ecological impacts that impact on agriculture or other income-generating activities, there may be ramifications for its likely success. Surveys of attitudes towards the reintroduction within local communities will therefore be carried out and any conflicts of interest resolved.

8.3.7 Post-release monitoring

Many amphibian species have cryptic life styles that render them extremely difficult to monitor. Consequently, research on the refinement of monitoring protocols will inform the design of post-release monitoring. Equally, the longer the generation time of the species the longer the timeframe needed for establishing ‘success’. In order to demonstrate whether the reintroduction has resulted in the founding of self-sustaining populations, each reintroduced species will be monitored for multiple generations. Population and habitat viability analysis will be used to develop the timeframes over which ‘success’ can be realistically assessed using demographic and habitat data.

8.4 Budget

There are many difficulties in deriving a generic budget for funding amphibian reintroductions. Because of the long-term nature of most reintroduction strategies it is probably unrealistic to persuade a single donor to commit funding for the entire duration of a project. However, a fund-raising strategy should be in place that should be consistent with the staged planning process mentioned above, so that breaks in the continuity of the project are avoided.

Recovery programmes are often funded through short-term grants which often make maintaining continuity of expertise problematical. The co-ordinating body for a reintroduction programme will usually be the local or national governmental conservation agency, and it will be the responsibility of this agency to ensure that the roles of different partners are clearly identified so that all parties are aware of their commitments. Personnel changes in either the lead agency or project partners can jeopardise reintroduction projects and the organisation of the reintroduction programme needs to account for this.

The logistics and costs of carrying out the activities required for a reintroduction programme will vary by an order of magnitude between taxa and regions, and there are very few estimates of costs for any amphibian conservation programmes. In England, the costs of carrying out development mitigation for great crested newt conservation – which embraces some but not all of the activities required for reintroduction – varied between £1350 and >£100,000 per project (Edgar et al. 2005). This variation was largely due to differences in the scale of the projects undertaken – some lasted a few days while others extended to several years. The costs in Table 1 are based on personal experiences of reintroduction programmes of four species of threatened amphibian in Europe (*Bufo calamita* and *Rana lessonae* in England; *Rana dalmatina* in Jersey; *Alytes muletensis* in Mallorca). The budget assumes that a thorough preliminary evaluation of the suitability of the species for reintroduction has already been performed by interrogation of the GAA, consultation with experts and literature survey. Some of the proposed activities may be short-term, and perhaps achieved within the timeframe of one year, while others will require a long-term commitment, but it is envisaged that no projects could be realistically completed in less than five years. However, the costs reflect the fact that certain activities (e.g. habitat management/threat mitigation) may require large initial outlays followed by rather lower annual maintenance budgets. Not all of the activities listed may be applicable to all projects and some projects may require specialist activities that are not listed. Economic circumstances may mean that projects carried out in tropical countries are proportionately cheaper, but this may be offset by higher travel costs and more difficult logistics. In most cases, reintroduction is likely to be a relatively expensive conservation option, particularly if it is combined with captive breeding. When a species can be conserved via habitat management/protection and/or threat mitigation the costs are likely to be considerably lower. Given current available expertise and methodologies, we propose that the ACAP reintroduction programme should initially focus on a priority list of 20 species that will be compiled following the species selection process.

Table 1. Suggested budget for carrying out an amphibian reintroduction programme in Europe or North America. Costs shown are proposed costs (US$) per species for projects of up to 10 years duration (some projects may require >10 years). Costs are based on travel, accommodation, equipment, consumables and overheads, but exclude staff salaries and/or student stipends.

	Duration of project		
Activity	**1 year**	**5 years**	**10 years**
Publicity, public relations and information	2000	4000	8000
Pre-release assessment of the wild populations	8000	40000	/
Applied ecological research on life history and hal requirements	10000	50000	/
Habitat management, restoration and creation and tl mitigation	15000	35000	450000
Population viability analysis and strategic recovery development	6000	/	/
Health monitoring and disease assessment	10000	18000	22000
Genetic assessment	20000	25000	30000
Local communities assessment	4000	/	/
Post-release monitoring	4000	20000	40000
Total	79000	192000	550000

8.5 Acknowledgments

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8.6 Literature Cited

Akcakaya, H. R., Burgman, M.A., Kindvall, O., Wood, C.C., Sjogren-Gulve, P., Hatfield, J.S. & McCarthy, M.A. (2004) *Species Conservation and Management: Case Studies*. Oxford University Press.

Beebee, T. J. C. & Griffiths, R. A. (2005) The amphibian decline crisis: a watershed for conservation biology. *Biological Conservation* **125**, 271-285.

Bloxam, Q. M. C. & Tonge, S. J. (1994) Amphibians – suitable candidates for breeding-release programmes. *Biodiversity and Conservation*, **4**, 636-644.

Buley, K. R. & Garcia, G. (1997) Recovery programme for the Mallorcan midwife toad. *Dodo*, **33**, 80-90.

Burke, R. L. (1997) Relocations, repatriations, and translocations of amphibians and reptiles: taking a broader view. *Herpetologica* **47**, 350-357

Caughley, G. 1994. Directions in conservation biology. *Journal of Animal Ecology* **63**, 215-244.

Cunningham, A.A., Daszak, P. & Hyatt, A.D. (2001) Amphibia. In: *Quarantine and Health Screening Protocols for Wildlife prior to Translocation and Release into the Wild.* (Ed. Woodford, M.H.) pp. 74-79, Office International des Epizooties (OIE), Paris, France & IUCN Species Survival Commission's Veterinary Specialist Group, Gland, Switzerland.

Griffith, B., Scott, J.M., Carpenter, J.W. & Reed, C. (1989) Translocation as a species conservation tool: status and strategy. *Science* **245**, 477-480.

Denton, J.S., Hitchings, S.P., Beebee, T.J.C., Gent, A., (1997) A recovery program for the natterjack toad (*Bufo calamita*) in Britain. *Conservation Biology* **11**, 1329-1338.

Dodd, C. K. & Seigel, R. A. (1991) Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? *Herpetologica* **47**, 336-350.

Edgar, P. W., Griffiths, R. A. & Foster, J. P. (2005) Evaluation of translocation as a tool for mitigating development threats to great crested newts (*Triturus cristatus*) in England, 1990-2001. *Biological Conservation* **122**, 45-52.

Fischer, J. & Lindenmayer, D. B. (2000) An assessment of the published results of animal relocations. *Biological Conservation*, **96**, 1-11.

IUCN (1998) *IUCN Guidelines for Re-introductions*. IUCN, Gland, Switzerland

Jones, C. G. (2002) Reptiles and Amphibians. In: *Handbook of Ecological Restoration. Volume 1: Principles of Restoration*. (M. Perrow et al., eds.). Cambridge University Press, pp. 355-375.

Norris, K. (2004) Managing threatened species: the ecological toolbox, evolutionary theory and declining-population paradigm. *Journal of Applied Ecology* **41**, 413-426.

Reading, R. P., Clark, T. W. & Griffith, B. (1997) The influence of valuational and organizational considerations on the success of rare species translocations. *Biological Conservation* **79**, 217-225.

Reinert, H. K. (1994) Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. *Herpetologica* **47**, 357-363.

Siegel, R. A. & Dodd, C. K. (2002) Translocations of amphibians: proven management method or experimental technique? *Conservation Biology* **16**, 552-554.

Wilson, A.C. & Stanley Price, M.R. (1994) Reintroduction as a reason for captive breeding. In: *Creative Conservation*. Olney, P.J.S. et al. (eds.). Chapman & Hall, London. pp. 243-264.

Zvirgzds, J., Stasuls, M. & Vilnitis, V. (1995) Reintroduction of the European tree frog (*Hyla arborea*) in Latvia. *Memoranda Soc. Fauna Flora Fennica* **71**, 139-142.

Soorae, P. and F. J. Launay. 2007. Guidelines of the International Union for the Conservation of Nature,(IUCN) for Re-Introductions and their Application to Amphibians. Chapter 24 <u>in</u>: Conservation and Decline of Amphibians, vol. 8A, Amphibian Biology, edited by H. Heatwole and J. Wilkinson. Surrey Beatty and Sons, Pty. Ltd., Chipping Norton (*in press*).

CHAPTER 24

Guidelines of the International Union for the Conservation of Nature (IUCN) for Re-introductions and their Application to Amphibians

Pritpal S. Soorae and Fredéric J. Launay

Abbreviations in test and references: AZA=American Zoo and Aquarium Association; CBSG=Conservation Breeding Specialist Group; IUCN/SSC=International Union for the Conservation of Nature/Species Survival Commission; NGO=non-governmental organization; PHVA=Population and Habitat Viability Analysis; RSG=Re-introduction Specialist Group;

I. INTRODUCTION

Re-introduction is becoming an increasingly important tool for the conservation of amphibians and reptiles. A total of 113 herpetofaunal re-introduction projects, the majority of which are on-going, have been inventoried by the IUCN/SSC Re-introduction Specialist Group (RSG). Thirty-two of these involve amphibians. The validity of these numbers is, of course, linked to the projects being documented by the RSG. In addition, there are accidental and other non-documented introductions not related to conservation. Furthermore, the level of detail included in documentation varies greatly among projects, from only the species, place and date to very comprehensive accounts of all stages of the re-introduction program. Re-introductions are taking place in all seven global IUCN statutory regions but the majority is in North America and the Caribbean. Because the number of re-introductions of amphibians is small, supplementary data from another group of terrestrial ectothermic vertebrates, the reptiles, are used as needed to illustrate some of the principles and problems.

Many (42%) herpetological re-introduction projects inventoried by the RSG are actually translocations of species (see below for definition); 31% are head-starting projects. Only 12% of the documented projects involved the release of captive-bred individuals and 2% the release of confiscated specimens. Ninety-six species of amphibians and reptiles are the subject of re-introduction, supplementation, introduction or substitution. About 40% of these are lizards and snakes introduced into North America and the Caribbean and skinks into New Zealand; amphibians account for only 25%. Re-introductions of amphibians have been particularly prevalent in Western Europe, North America and the Caribbean, a reflection of the efforts made in these areas to assess amphibian diversity and restore populations at risk. In general, the status of amphibian populations are better known than are those of reptiles.

More than 53% of the species of amphibians and reptiles that have been re-introduced are not in the IUCN "Red List of Endangered Animals & Plants". This fact alone should stimulate re-thinking of global conservation strategies; most action is undertaken by dedicated individuals or groups of individuals at a very local scale. The present chapter reviews the IUCN/SSC re-introduction guidelines for amphibians and reptiles and extracts the key elements underlying the worldwide effort to re-introduce these animals.

II. DEFINITIONS AND TERMINOLOGY

A. Re-introduction

Re-introduction is an attempt to establish a species in an area that was once part of its historical range, but from which it has been extirpated (IUCN 1998). Major projects on amphibian re-introductions include the Mallorcan midwife toad (*Alytes muletensis*) in Mallorca, Spain (Buley and Gibson 1999), the Puerto Rican crested toad (*Peltophryne lemur*) in Puerto Rico (Johnson 1980) and the Wyoming toad (*Bufo baxteri*) in the United States (Spencer 1999).

1. Reinforcement (Supplementation)

Reinforcement, also called supplementation, is the addition of individuals to an existing population of conspecifics (IUCN 1998). The axolotl (*Ambystoma mexicanum*) in Mexico has been proposed for supplementation using captive-bred specimens but this has been discouraged because of considerable genetic and disease risks; also threats to wild populations have not been removed. Currently efforts are underway to clean polluted areas and reduce the threats (Griffiths *et al.* 2004).

2. Benign Introduction

Benign introduction is an attempt to establish a species, for the purpose of conservation, outside its recorded distribution, but within an appropriate habitat and eco-geographical area. This technique should be employed only when there is no remaining area left within the species' historic range (IUCN 1998). The frogs *Leiopelma pakeka* and *L. hamiltoni* have been moved to two different islands that are within an appropriate habitat and eco-geographical area. It is not certain whether this range is considered strictly out of their recorded distribution but there are no recent records of frogs from these islands nor have any fossils been found that would indicate them to be part of the historical range (Phil Bishop, personal communication).

3. Substitution

Substitution is the introduction of a species or subspecies to replace a closely related one that has become extinct both in the wild and in captivity. The substitute is introduced into suitable habitat within the extinct species' former range (Seddon and Soorae 1999).

4. Introduction

The introduction of an organism is the intentional or accidental dispersal by human agency of a living organism to an area outside its historically known native range (IUCN 1987). Cane toads (*Bufo marinus*) have been introduced into a number of places including Australia and the United States and its affiliated areas (Florida, Virgin Islands, Guam, American Samoa) where they have become invasive (McCoid 1995).

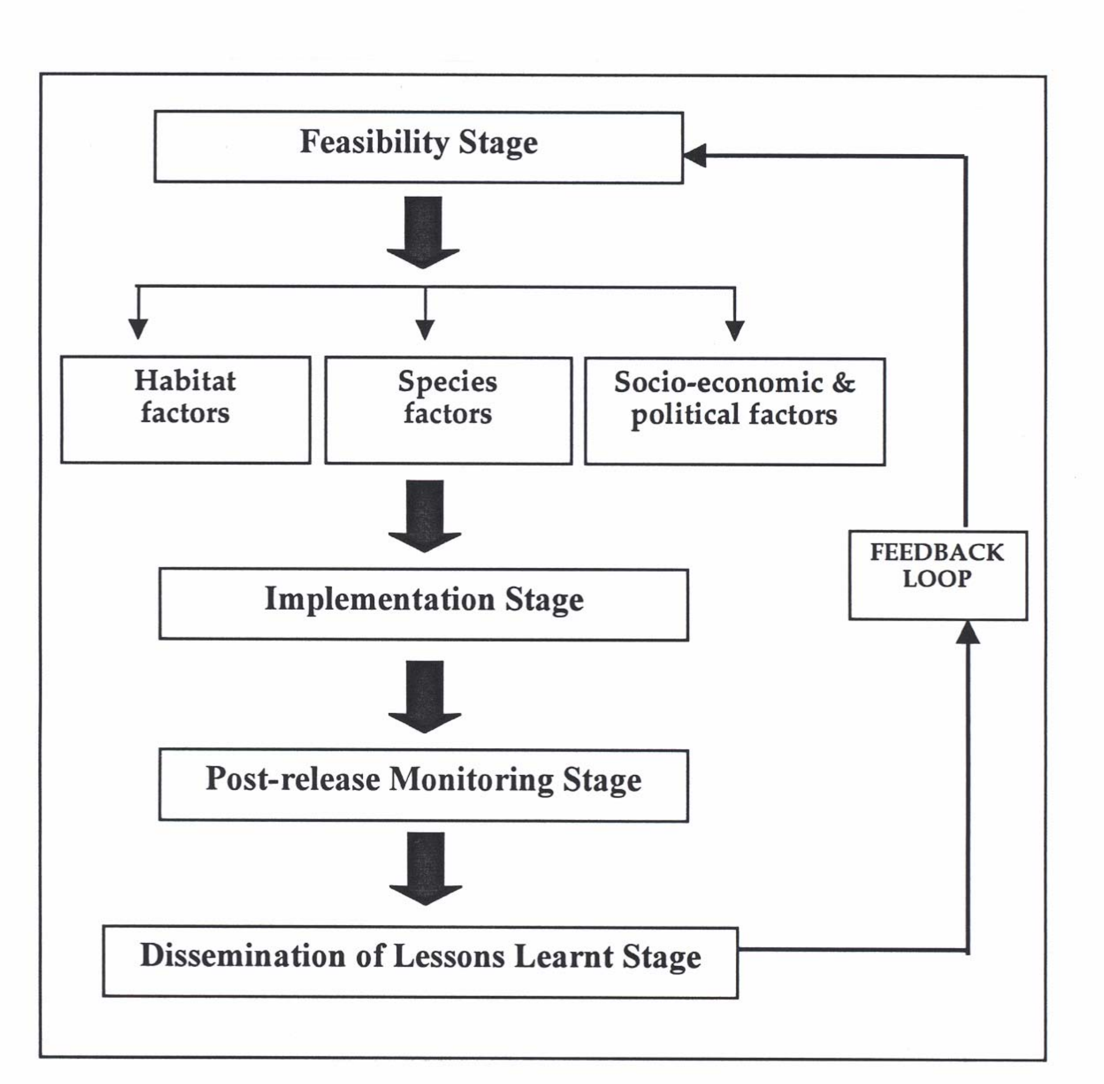
5. Translocation

Translocation is the movement of animals from one part of their geographic range to another (IUCN 1998).

III. MAIN STAGES OF A RE-INTRODUCTION PROJECT

A diagram of the stages through which a re-introduction project should progress is shown in figure 1.

Fig. 1. **Main stages of a re-introduction project.**



A. Feasibility Stage

During the feasibility stage (Fig. 1) it is important to know the main objectives of the proposed re-introduction project; these may include:

- Enhancing the long-term survival of a species
- Establishing a keystone species (in the ecological or cultural sense)
- Maintaining and/or restoring natural biodiversity

- Providing long-term economic benefits to the local and/or national economy
- Promoting conservation awareness

There are three main critical factors to be considered when planning a re-introduction: (1) habitat, (2) the species involved and (3) the socio-economic and political situation.

1. Habitat

A. CHOICE OF THE RE-INTRODUCTION SITE

Re-introductions ideally should be within the historic geographic range of the species. In order to prevent the spread of diseases, and to avoid social disruption and the introduction of alien genes, there should be no remnants of the original wild population remaining in localities receiving the introduced individuals (IUCN 1998). The Mallorcan midwife toad (*Alytes muletensis*) was re-introduced within its historical range, but into isolated sites currently lacking toad populations. These sites are selected, assessed and prepared using "site criteria points". In theory, full conformity to these points provides a released population its best chance for establishment and growth. The success of the project is highlighted by the fact that 25% of the wild population originated from captive-bred toads and there has been 100% range expansion (Buley and Gibson 1999).

In projects involving a re-enforcement there should only be a few remnant wild individuals (IUCN 1998). Headstarted Jamaican iguanas (*Cyclura collei*) were released into their natural habitat because prior observations had suggested that the wild population existed at a very low density and certainly below carrying capacity (Hudson 1999). Reinforcement projects can be used to remove the threat of genetic bottlenecks, or to correct skewed sex and/or age ratios. Of course, this procedure should be implemented only after the prior causes of the decline or altered population structure have been eliminated or reduced to a sustainable level. Alternatives to reinforcement may sometimes be desirable. For example, the western swamp tortoise (*Pseudemydura umbrina*) re-introduction project in Australia did not release any captive-bred individuals into the last-remaining stable population but instead re-introduced them into an alternative site (Kuchling 1999).

B. EVALUATION OF THE RE-INTRODUCTION SITE

Re-introduction should only take place when the habitat and landscape requirements of the species are satisfied and changes since extirpation have been considered (IUCN 1998). In New Zealand, re-introdution of the Maud Island frog (*Leiopelma hamiltoni*) has been possible because the release site has been gazetted as a reserve and previous farmland is rapidly regenerating into forest (Gaze 1999). It is important to have access to baseline information spreading over a considerable length of time so that temporal changes can be reviewed and evaluated.

In some cases, there may be habitat changes in addition to the presence of invasive species.

Sometimes unsuitable habitat can be improved. Gent (1999) mentioned that acidic ponds are highly toxic to the spawn of natterjack toads (*Bufo calamita*) and also harbour a higher number of predators. Addition of quicklime to experimental ponds reduced the pH and eliminated acid-induced mortality of both embryos and tadpoles.

The release site should have a sufficient carrying capacity to support a viable, self-sustaining population in the long-term (IUCN 1998). The area required to support a viable, self-sustaining population can vary from a small cave hosting the endemic Romer's frog (*Philautus romeri*) in Hong Kong (Dudgeon and Lau 1999) to a range extension from 100 to 200 km^2 for the Mallorcan midwife toad (*Alytes muletensis*) (Buley and Gibson 1999).

The original cause of decline must be identified and either eliminated or reduced to a sufficient level before initiating a re-introduction project (IUCN 1998). Populations of the Tarahumara frog (*Rana tarahumarae*) have declined in Arizona, United States, due to unclear factors but chytridiomycosis, a fungal skin disease associated with amphibian population decline worldwide, has been associated with some of the declines. It also seems that pollutants from copper smelters in the region could have compromised immune functions resulting in an increased susceptibility to chytridiomycosis. The smelters have now either closed or have installed pollution-control scrubbers (Rorabaugh 2004).

Other reasons for decline include disease, over-hunting, over-collection (exotic species for the pet trade), pollution (especially for amphibians that are aquatic breeders), poisoning, adverse effects of earlier research or management programs, and competition.

C. HABITAT RESTORATION

If the potential release-site has undergone substantial degradation then restoration of the habitat must be carried out before re-introduction can proceed (IUCN 1998). The re-introduction of the Mallorcan midwife toad (*Alytes muletensis*) was limited by the availability of suitable new release sites. A novel idea involved the use of man-made "cisterns", built centuries ago for watering sheep and goats as these toads were found to be utilizing them as breeding sites (Gibson and Buley 1997). Restoration of habitat can be directed toward certain critical activities (e.g., breeding as for Mallorcan midwife toads mentioned above) or stages in the life-cycle (providing small fish-free pools to avoid predation upon larvae as has been done for Romer's frog, *Philautus romeri*, in Hong Kong (Dudgeon and Lau 1999).

2. Species

A. FEASIBILITY AND BACKGROUND

The individuals used for introductions must be selected with care. In most cases it is preferable to use wild animals.

A captively bred individual's probability of survival in the wild must approximate as closely that of its wild counterpart (IUCN 1998).

In captivity the effects of domestication can lead to loss of important skills needed for survival, such as predator-avoidance, ability to capture prey, and knowledge of seasonal migration routes. For example, Kuchling (1999) noted that inexperienced and naïve tortoises were more prone to predation than were those that had survived their first year in the wild.

Loss of essential skills is probably more of a problem in mammals and birds than it is in ectothermic vertebrates that are considered to be “hardwired” and generally more successful in surviving in the wild after release (see Hudson 1999). The possibility should be considered and individuals tested, however, before release. Tolson (1999) found that two out of 23 captive-born Virgin Islands boas (*Epicrates monensis*) could not successfully catch live *Anolis cristatellus* in a trial; those individuals were not released.

If captive-bred individuals have to be used, they should come from a population that has been managed both demographically and genetically (IUCN 1998). The fewer the number of generations spent in captivity, the more likely it is that the genetic make-up of the animals will have remained intact (Burbidge and Kuchling 1994).

A Population and Habitat Viability Analysis (PHVA) can aid in identifying significant environmental and populational variables and in assessing their potential interactions. This information can be used to guide long-term population management (IUCN 1998). The IUCN/SSC Conservation Breeding Specialist Group (CBSG) conducted a total of 11 PHVA workshops for reptiles and amphibians, of which five covered amphibians exclusively (CBSG personal communication, 2005).

Surplus stocks of animals sometimes become available from breeding programs in zoos or are confiscated from illegal or irregular trade. The maintenance of such animals in captivity is expensive and sometimes they are released as a means of disposing of them. Re-introductions, however, should never be carried out merely because surplus individuals are available (IUCN 1998).

Diseases can have devastating effects on wild populations (see Chapters 2-4), e.g., an infection by the fungus *Basidiobolus ranarum* nearly caused the extinction of the Wyoming toad (*Bufo hemiophrys baxteri*). Consequently, individuals destined for re-introduction must meet all necessary health requirements (IUCN 1998). Translocated individuals also can import new parasites or pathogens that may affect resident conspecifics in the new location. For example, in Arizona, United States, unwanted desert tortoises (*Xerobates agassizii*) infected with an upper respiratory tract disease were released into the wild and spread this disease among wild populations (Woodford 1993). The bacterium *Acromonas hydrophila* (the cause of a disease called red leg in frogs) normally occurs in captive animals but can also be a problem in the wild (Seal 1994).

There is also the possibility of immunologically naïve animals being released into areas where they become exposed to endemic pathogens against which they have little or no resistance (Cunningham 1996).

3. Socio-economic and Political Factors

A. FINANCIAL AND POLITICAL SUPPORT

Re-introductions are usually long-term, expensive projects that require sustained financial and political support. Socio-economic studies should be conducted to assess impacts and the costs and benefits to local communities (IUCN 1998).

In 1984 the Fish and Wildlife Service (FWS) listed the Wyoming toad (*Bufo hemiophrys baxteri*) as an endangered species. To protect the remaining populations the Nature Conservancy stepped in and assisted by purchasing 1,800 acres of land which included Mortenson Lake and surrounding areas (Spencer 1999). This did not help and by 1994 the species was extinct in the wild with only a captive population remaining. The recovery-effort for this toad consists of eight zoos of the American Zoo and Aquarium Association (AZA), another zoo that maintains the species studbook, and two government facilities. In total there are 600 toads in captivity and over 3,000 historical records in the studbook. Since 1996, efforts at re-introduction have focused on the Mortenson Lake refuge.

The Jamaican iguana recovery effort illustrates an approach on three fronts: (1) there was a dedicated team of conservation biologists, (2) both government and NGOs provided salaries for essential field personnel, and (3) over 20 AZA zoos contributed financial, technical and logistical support and raised nearly US $100,000 (Hudson 1999).

Human activities may pose a risk to re-introduced populations. For example, releases of Orinoco crocodiles (*Crocodylus intermedius*) in Venezuela were affected when one of the project facilities became the target of vandalism during political upheavals (Ross 1995). Counter measures to counteract the effect of human disturbances should be undertaken. If those are not successful, then alternative release areas should be sought and the initial sites abandoned (IUCN 1998).

B. POLICIES AND MIGRATORY SPECIES

Existing provincial, national and international policies regarding re-introductions should be assessed and full permission obtained. Involvement of all relevant government agencies should be sought, remembering that re-introductions can occur in border areas, and that species might expand into states, provinces or other territories across boundary lines (IUCN 1998).

In Britain, great crested newts (*Triturus cristatus*) have been translocated in high numbers to enable building projects. Legislation since the early 1980s has, in theory, protected both the animal and habitat. Since the habitat is not designated, however, a site can be destroyed for development as long as the newts are translocated to a new location. This legal “loophole” has been exploited with increasing frequency (Langton 1999). Although a large number of new ponds were created to compensate for those lost to building projects, there was still a net loss in area of aquatic habitat (Edgar *et al.* in press).

B. Implementation Stage

During the implementation stage it is important to get the approval of relevant governmental agencies, land owners, NGOs (both local and international) and to establish a multidisciplinary team to oversee the project. It is also important to identify both short-term and long-term indicators (IUCN 1998). The description of the release program of the Puerto Rican crested toad (*Peltophryne lemur*) indicates that "the success of re-introduction programs must be considered in a time frame of perhaps ten or more years, and after a number of releases" (Johnson 1980). A translocation may be deemed successful if new populations are self-sustaining and comprised only of locally bred animals.

Extreme longevity and prolonged post-release monitoring can be a problem for the translocation of some species (Towns and Ferreira 2001). For example, individuals of certain long-lived skinks in New Zealand are still being caught 12 years after release.

It is important to ensure that secure funding is available for all phases of the project (IUCN 1998). The re-introduction of the European pond turtle (*Emys orbicularis*) in France was approved and financed from 2000–2002 by the European Union (Life Nature Lake of the Bourget), the French Environment Ministry, the Rhone-Alpes Reion and the Savoie Departmental Council (Cadi and Miquet 2003).

All veterinary protocols should be in place (IUCN 1998). The welfare of animals should be of high concern at all stages of the project (IUCN 1998). During the transfer in New Zealand of Maud island frogs (*Leiopelma hamiltoni*) from the point of capture to the release site, these small animals were placed in inflatable re-sealable plastic bags with a folded wet tissue. The bags were stored in coolers to maintain a uniform temperature (Gaze 1999).

C. Post-release Monitoring Stage

Post-release monitoring is an extremely important stage because without it the success of the programme cannot be evaluated (IUCN 1998). A number of common hourglass tree frogs (*Polypedates cruciger*) were released at the site of egg-collection in Sri Lanka after hatching in a laboratory. They were not marked before release and could not be monitored (de Silva 1994) and their fate was unknown.

Monitoring of released individuals can be achieved directly by equipping all, or a sample, of individuals with tags or telemeters, or indirectly by examination of spoor or by interviewing informants (IUCN 1998). Small cryptic amphibians such as Maud Island frogs (*Leiopelma hamiltoni*) are monitored by capture/recapture methods (Gaze 1999).

Long-term studies on adaptation, ecology and behaviour of released animals ideally should be undertaken (IUCN 1998).

D. Dissemination of Lessons Learned

Results of projects, whether successful or not, should be published in scientific and popular literature (IUCN 1998). The IUCN/SSC Re-introduction Specialist Group (RSG) has published 23 newsletters since November 1990 and 11% of the articles have been on re-introductions of amphibians and reptiles. One issue (No. 17) was devoted solely to that topic (RSG Secretariat 2004).

Personnel involved in re-introductions should learn from past successes and failures as a means of improving the design of projects (IUCN, 1998).

Cost-benefit analyses should be carried out on projects (IUCN 1998). During an Orinoco crocodile (*Crocodylus intermedius*) release program in Venezuela, crocodiles three to four years of age were being released as they were less susceptible to predation. Later, however, one-year-old individuals were released, and the risk of greater mortality accepted because of various economic and ecological considerations (de Blohm 1993). In terms of resources it costs more to maintain crocodiles longer in captivity and it was found that releasing them at a younger age did have an initial effect on growth but over time their growth and development was normal (Valesco 1999).

Dissemination of information through the mass media is very important to keep the public informed about a project (IUCN 1998). The future goals of a recovery-effort for the Wyoming toad (*Bufo hemiophrys baxteri*) include increasing the public awareness of the critical status of this species, expansion of the captive-breeding program, conducting additional research, and targeting outreach programs for adults and for students in local schools (Spencer 1999). Re-introduction programs involving snakes have also experienced difficulties arising from the fear and dislike of snakes by decision-makers and the general public (Daltry *et al.* 2001).

Lessons learned from re-introductions must feed into future projects to ensure that successes and failures are evaluated and reviewed, thereby leading to better project design and avoiding repetition of mistakes. Re-introduction projects always should be conducted as carefully designed scientific experiments (IUCN 1998).

E. Review of Amphibian and Reptilian Projects

An analysis was made of a total of 24 re-introduction projects from the archives of the RSG's newsletter, *Re-introduction NEWS*, published since 1990. Eight of these were re-introductions involving amphibians; the others dealt with crocodilians (3), turtles (7), and lizards and snakes (8). The latter groups have been included because of the paucity of studies on amphibians and because they illustrate important points of likely relevance to future amphibian studies.

The analysis examined (1) habitat, (2) species, and (3) socio-political and economic factors. The conclusions from these are summarized in turn.

1. Habitat Factors

A. REASONS FOR DECLINES:

Unsustainable hunting, loss of nesting habitat, pollution, livestock overgrazing, poaching, bushfires, habitat fragmentation, road mortality, introduced predators, acidification of breeding ponds, competition, loss of natural processes (e.g., tidal inundation and stabilization of dunes), loss of wetlands and forest cover, drainage and siltation of breeding ponds, and collection for the pet trade have all been implicated in amphibian declines.

B. HABITAT RESTORATION PRIOR TO RELEASES:

Vegetation regeneration, engineering of ponds, physical removal of trees and shrubs to create open habitat, removal of predators (e.g., rats), desilting of old ponds and construction of artificial burrows are ways of preparing a site for subsequent re-introduction.

2. Species Factors

Release stock: Individuals destined for release undergo genetic evaluation, are checked for disease and are evaluated in terms of their fitness for survival (tested for predator avoidance skills and capability to hunt prey).

Release strategy: Headstarting, release of yearling turtle hatchlings, release of captive-bred tadpoles, wild-to-wild translocations and acclimatization in enclosures containing natural vegetation before their release. In amphibian projects a large number of larvae are released over many years before populations become established. In tropical habitats with marked wet and dry seasons aquatic species introduced again following loss of habitat during the dry season.

Post-release monitoring: Techniques employed are finger clipping, radio-transmitters, monitoring calls during the breeding season, noting presence of tadpoles as indicative of reproduction, recaptures, tagging and tail-notching.

3. Socio-political and Economic Factors

Public relations: Involves the sensitization of people by the distribution of posters, life-size models of toads, educational videos, school lectures and through controlled tourism. The European tree frog (*Hyla arborea*) re-introduction project in Latvia has been successfully completed over a span of 10 years. In 1997, this project was awarded the prize of the Council of Ministers of the Republic of Latvia as a contribution to biodiversity (Zvirgzds 1999).

Local communities: There are cases in which the transfer of species is done with the approval of local tribes. In a New Zealand example, the ownership of Maud Island frogs (*Leiopelma hamiltoni*) was transferred from the *Ngati Kuia* tribe (*Maori* tribe with affiliations to Maud Island) to the *Te Atiawa* tribe (tribe on Motuara Island) in a brief tribal ceremony held on the beach (Gaze 1999). Local communities have also been used for the post-release monitoring of released individuals.

Fund-raising: Funds for re-introduction programs are raised through a multitude of sources such as non-governmental organizations, governmental organizations, zoos and universities, amongst a host of other organizations. The Puerto Rican crested toad (*Peltophryne lemur*) initiative has obtained funds from the American Zoo and Aquarium Association and individual grants from zoos (Johnson 1999). The Romer frog (*Philautus romeri*) re-introduction in Hong Kong was funded by the Royal Hong Kong Jockey Club Charities Ltd. (Dudgeon and Lau 1999).

IV. REFERENCES

Buley, K. R. and Gibson, R. C., 1999. The recovery program for the Mallorcan midwife toad, Mallorca, Spain. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 5-6.

Burbidge, A. A. and Kuchling, G., 1994. Western Swamp Tortoise Recovery Plan. *Western Australia Wildlife Management Program* No. **11**: 9-10.

Cadi, A. and Miquet, A., 2003. First release of the European pond turtle release program in Lake Bourget, France. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE* No. **22**: 44-45.

Cunningham, A. A., 1996. Disease risks of wildlife translocations. *Conservation Biology* **10**: 349-353.

Daltry, J. C., Bloxam, Q., Cooper, G., Day, M. L., Hartley, J., Henry, R., Lindsay, K. and Smith, B. E., 2001. Five years of conserving the 'worlds rarest snake', the Antiguan racer (*Alsophis antiguae*). *Oryx* **35**: 119-127.

Dudgeon, D. and Lau, M. W. N., 1999. Romer frog re-introduction into a degraded tropical landscape, Hong Kong, P. R. China. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 10-11.

de Silva, A., 1994. Common hourglass tree frog in Sri Lanka. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **8**: 9.

de Blohm, C., 1993. Orinoco crocodiles in Venezuela. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **6**: 5.

Edgar, P. W., Griffiths, R. A. and Foster, J. P., Evaluation of translocation as a tool for mitigating development threats to great crested newts (*Triturus cristatus*) in England, 1990-2001. *Biological Conservation*, in press.

Gaze, P., 1999. Translocation of the Maud Island frog in the Marlborough Sounds, New Zealand. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 9-10.

Gent, T. 1999. Conservation of the natterjack toad in England and Wales, looking specifically at the role of translocations. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 6-8.

Gibson, R. C. and Buley, K. R., 1997. Mallorcan midwife toad release. *Memorandum to IUCN Re-introduction Specialist Group from Jersey Wildlife Preservation Trust.*

Griffiths, R., Graue, V., Bride, I. G. and McKay, J. E., 2004. Conservation of the axolotl (*Ambystoma mexicanum*) at Lake Xochimilco, Mexico. *Herpetological Bulletin* No. **89**: 4-11.

Hudson, R., 1999. The recovery strategy for the Jamaican iguana, Jamaica. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 19-21.

IUCN, 1987. "The IUCN Position Statement on Translocation of Living Organisms: Introductions, Re-introductions and Re-stocking". Prepared by the Species Survival Commission in collaboration with the Commission on Ecology, and the Commission on Environmental Policy, Law and Administration, IUCN. Gland, Switzerland.

IUCN, 1998. "Guidelines for Re-introductions". Prepared by the IUCN/SSC Re-introduction Specialist Group, IUCN. Gland, Switzerland and Cambridge, UK.

Johnson, R. R., 1980. Release and translocation strategies for the Puerto Rican crested toad (*Peltophryne lemur*). *Endangered Species Update* **8**: 8-9

Kuchling, G., 1999. Re-introduction of the western swamp tortoise, Australia. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 13-14.

Langton, T., 1999. Great crested newt re-introductions in Britain. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 11-12.

McCoid, M. J., 1995. Non-native reptiles and amphibians. Pp. 433-437 *in* "Our Living Resources: a Report to the Nation on the Distribution, Abundance, and Health of U. S. Plants, Animals, and Ecosystems", ed by E. T. Laroe, G. S. Farris, C. E. Puckett, P. D. Doran and M. J. Mac. U. S. Department of the Interior, National Biological Service, Washington, D.C.

Rorabaugh, J., 2004. Re-establishment of the Tarahumara frog into Arizona, USA. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE* No. **24** (in press).

Ross, J. P., 1995. Re-introduction of crocodiles. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **10**: 15-16.

Seal, U. S., 1994. Population and habitat viability assessment. Report of workshop conducted by CBSG in partial fulfillment of USFWS Contract No. **94-172**: 90

Seddon, P. and Soorae, P. S., 1999. Guidelines for Subspecific Substitutions in Wildlife Restoration Projects. *Conservation Biology* **13**: 177-184.

Spencer, B., 1999. The Wyoming toad SSP. *Endangered Species Bulletin* **24**: 18-19

Tolson, P., 1999. Re-introduction of the Virgin Islands boa to the Puerto Rico Bank, The Caribbean. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 22-23

Towns, D. R. Ferreira, S. M., 2001. Conservation of New Zealand lizards (Lacertila: Scincidae) by translocation of small populations. *Biological Conservation* **98**: 211-222

Valesco, A. B., 1999. Re-introduction program of the Orinoco crocodile in Venezuela. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 24-25.

Woodford, M. H., 1993. International disease implications for wildlife translocations. *The Journal of Zoo and Wildlife Medicine* **24**: 268-269

Zvirgzds, J., 1999. The European tree-frog re-introduction in Latvia. *Re-introduction NEWS, Newsletter of the IUCN/SSC Re-introduction Specialist Group, Nairobi, Kenya* No. **17**: 8-9.

Kihansi Spray Toad (*Nectophrynoides asperginis*) Population and Habitat Viability Assessment Briefing Book

Section 8:
Other

14-17 May 2007
Bagamoyo, Tanzania

Can a unique amphibian be saved after its environment has been transformed? Scientists do their best but fear the worst

The Lost World of the Kihansi Toad

BRONX ZOO, NEW YORK CITY—Past the snake exhibit, where gigantic pythons lurk behind thick glass, in the back rooms of the Reptile House, sits a humid, low-ceilinged isolation chamber. Here in five plastic terraria, 159 mustard-colored, fingernail-size amphibians are making what could be their last stand on Earth.

The Kihansi spray toad is 12,800 kilometers from home: Kihansi Gorge, in Tanzania's remote Udzungwa Mountains. For millions of years a great waterfall filled this gorge with perpetual spray and wind, creating a singular environment where the toad and other endemic creatures lived. In 2000, a hydropower dam cut off 90% of the water, and the ecosystem withered. Since then, scores of scientists in many disciplines have performed elaborate, unprecedented deeds to salvage the toad and its lost world. They have managed to raise the toads in captivity, documented the ecosystem's myriad responses to the dam, and engineered in the gorge what may be the world's largest sprinkler system. Their story shows that although human technology can easily upset nature, even the best science may not suffice to restore it.

In splendid isolation

The cool, high peaks of the Udzungwas jut from a sea of dry savanna, forming part of the Eastern Arc Biodiversity Hotspot, a crescent-shaped archipelago of nine mountain ranges. Here are some of the world's oldest rainforests, where long isolation and stable climate have given biota tens of millions of years to evolve. Thousands of plants and animals are endemic to the nine ranges, to one range, or, as in Kihansi, one locale. The spray toad has what may be the smallest range of any vertebrate—2 hectares. Some biologists think it has lived in the gorge or nearby for at least 10 million years.

The gorge begins where the Kihansi River plunges 100 meters off an escarpment, then rushes another vertical 750 meters through 4 kilometers of violent twists and cascades. The river flows year-round, whereas the region's other streams disappear in dry season. The slippery cliffs and the water's ferocity long excluded people, allowing the mist-world creatures to live undisturbed and undiscovered.

Steep drop and dependable flow also are ideal for hydropower. In 1983, engineers envisioned diverting water via a dam above the gorge to a turbine-filled tunnel; flow would bypass the gorge and return to the riverbed at the bottom. A survey of the modest 20-hectare proposed reservoir suggested an environmentally benign project, and in 1994, construction began on the $270 million effort, initially funded by World Bank loans. Development banks in Norway, Sweden, and Germany later joined but insisted that downstream biota be surveyed too.

Thus in 1996, with the dam infrastructure already partly built, biologists including herpetologist Kim Howell of the University of

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Out of water. After a sprinkler system (*left*) replaced the waterfall (*inset*, *right*), Kihansi toads (*inset*, *left*) became vanishingly rare.

Dar es Salaam managed to climb down into several steep, mist-engulfed meadows. Here they found an estimated 50,000 of the skinny, endearing toads, hiding in deep moss mats. Although they have relatives in the region, several unusual features set the toads apart, including flaps over nostrils (possibly to keep out excess spray) and live births (eggs might wash away). Their *chit-chit-chit-chit* call can ramp up to high frequencies inaudible to humans, possibly to overcome constant low-end waterfall roar, says evolutionary biologist Corinne Richards of the University of Michigan, Ann Arbor. The toads ate hundreds of wetland insect species, most still unidentified. Biologists also found at least four new endemic plants in the gorge, including a new coffee species, plus rare trees and threatened primates and birds.

But even as they explored the gorge world, biologists had scant hope for preserving it. "As soon as we found this place, we knew it would be going extinct," says one foreign consultant—who, like several others, feared being quoted by name because of the fierce politics surrounding the dam. To compensate, biologists sought possible toad transplant sites but turned up nothing. They recommended letting half the river's flow continue to the gorge, but that recommendation was not followed. In 1999, European newspapers got wind of unpublished studies, along with the published description of the toad, *Nectophrynoides asperginis*. Groups such as Friends of the Earth accused the banks and Tanzania of violating the International Convention on Biological Diversity, which forbids projects that would wipe out species.

The government and lenders compromised. With an added $6 million loan to cover conservation studies and mitigation, the gorge would get 10% of its previous flow. Part was to be channeled into a several-kilometer-long, gravity-fed pipe system snaking down rock walls to the toad meadows, where hundreds of spray nozzles would spurt mist—a setup meant to mimic natural spray with a fraction of the water. Covering a quarter of the toads' original habitat, the sprinklers are "probably the most highly engineered recovery system for any species ever," says William Newmark, a conservation biologist at the Utah Museum of Natural History advising the World Bank.

But the sprinklers were not ready when the water was to be choked off in early 2000. The shutoff proceeded anyway, and by the time the sprinklers came on 9 months later, the ecosystem had dried up catastrophically. Common plants from adjacent dry areas had invaded former spray meadows; mosses had declined almost 95%; insect diversity had dropped; and only 2000 toads were left alive.

Doing the downstream conservation work only after the dam was well under way was a "huge mistake: Planning was not preceded by a thorough and complete environmental impact assessment," admits conservation biologist Wilfred Sarunday, coordinator of Tanzania's Lower Kihansi Environmental Management Project, which oversees studies and mitigation at the gorge.

In captivity

Fearing the toads would soon be extinct, in December 2000, the Tanzanian government allowed the Wildlife Conservation Society to collect 500 animals for breeding in a half-dozen U.S. zoos. But captive amphibians are difficult to raise, and the animals soon were plagued with lungworms, infections, bone problems, intestinal parasites, and nutritional deficiencies. They would not breed predictably. By spring 2004, the Bronx and Toledo (Ohio) zoos had the only survivors—about 70.

The Bronx Zoo took two unusual steps. It called in the Coriell Institute, a Camden, New Jersey, human genetics outfit that preserves cell lines for research. Their staff created cell lines from dying toads, in hopes that technology would one day permit cloning the cells back into whole creatures. But the cell lines all died. The zoo also farmed out a dozen tiny corpses to Valerie Clark, a Cornell University chemist who studies potentially valuable bioactive substances harbored by amphibians. It was "our last chance" to analyze the toads, says Clark, who plans tests.

Then, in 2005, the captives perked up. Keepers had devised treatments for various ailments and discovered that although the standard zoo ultraviolet lamps were too big and crude, the toads liked basking in the narrow beams of little 12-volt track-light bulbs. Slowly, the toads started having babies—so small that keepers at first thought they were ants. Now there are about 300 toads between the two zoos.

Meanwhile, in Kihansi, things briefly got better—then much worse. After the sprinklers came on in early 2001, wetland plants slowly regenerated, according to a paper last year in *Biodiversity and Conservation* by Claire Quinn of the University of York, U.K. Some severely affected toad prey such as an endemic *Ortheziola* scale insect also increased, says Peter Hawkes, a consulting entomologist in Pretoria, South Africa. Most encouraging were the toads; internal reports indicate that by June 2003, some 20,000 were hopping about.

A month later, the toads crashed. In August 2003, 40 were seen; in January 2004, only five. Since then, they have virtually disappeared. Once or twice a year, site workers say they hear calls, and in May 2005, a biologist claimed to see one individual. Some scientists say it is still too early to talk about extinction in the wild, but many are pessimistic. "Seeing one spray toad is like … [seeing] one passenger pigeon," says James Gibbs, a herpetologist at the State University of New York at Syracuse who monitors the gorge for the World Bank. "The

Holding on. Kihansi toads now thrive only in zoo terraria (*top*), where keepers managed to get them to breed.

place is not what it used to be. Nobody wants to say it out loud, but it may be too late."

Biologists point to several possible suspects. The immediate cause may have been chytrid fungus, a deadly skin infection implicated in amphibian crashes around the world, says herpetologist Ché Weldon of North-West University in Potchefstroom, South Africa. His data show that the fungus was absent earlier but present by the crash. One candidate for bringing it in: the imported sprinkler pipes. Another: the boots of dozens of scientists, who traveled in from four continents. Others point out that the 2003 crash coincided neatly with a brief opening of the dam's floodgates to flush sediments. Tests showed these contain pesticides used by a growing number of maize farmers upstream, in concentrations that could kill the toads.

But these are just immediate causes. At bottom, many believe that the gorge environment is broken and can't be reassembled: The changes weakened the toads, and chemicals or infections just finished them off. For instance, the waterfall had constantly replenished spray-meadow soils with wet silt; the sprinklers just sprinkle water, leaving soil crumbly and susceptible to erosion. The waterfall's force also generated ceaseless wind—not supplied by sprinklers—whose now-vanished role in the ecosystem remains unknown. "It's not clear how successful the artificial system is," says water-resources engineer John Gerstle of Hydrosphere Resource Consultants in Boulder, Colorado, who managed much of the environmental work at the gorge until 2004. "It is hard to mimic a situation when you don't necessarily understand it."

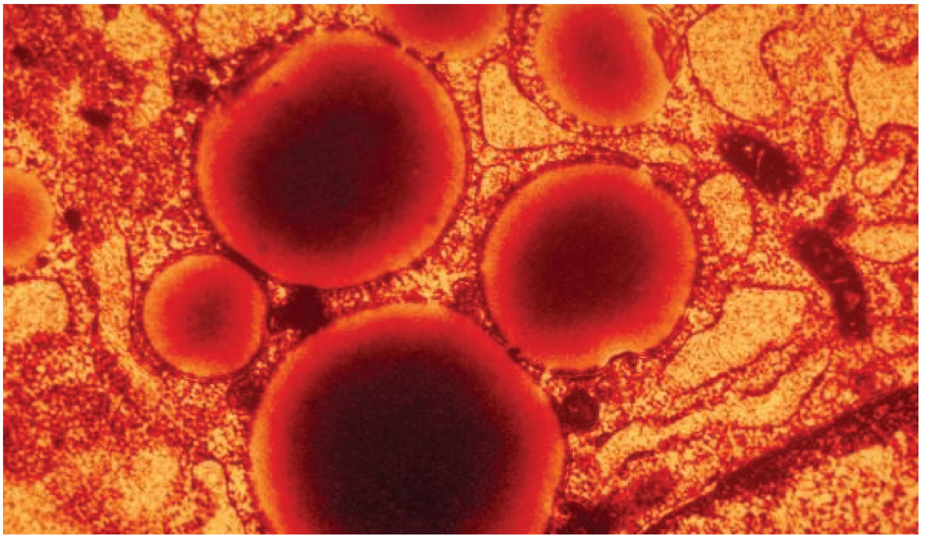
The situation has brought down continuing ire on scientists and their employers. Friends of the Earth President Brent Blackwelder recently wrote to the World Bank: "[Y]our monitoring team is passively documenting the extinction of this unique ecosystem." Sarunday, who still hopes that the system will recover, insists that the banks and Tanzania have "acted in good faith." In one letter to the group, then–World Bank Vice President for Africa Callisto Madavo wrote that measures at the gorge were "designed to ensure an optimal balance between biodiversity conservation and economic development."

The gorge also highlights tensions between developed nations, who funded the dam, and Tanzania, which now gets a third of its electricity from it. Tanzania is one of the most conservation-oriented African nations, but most observers doubt it would have borrowed $6 million for environmental work without pressure from "donor" nations, who want the money repaid. "Most [Tanzanians] say: Who cares about a toad? We want our electricity," says Tanzanian ornithologist Norbert Cordeiro, now at Chicago's Field Museum. When the captive toads were flown on a jet to New York, one Tanzanian newspaper pointed out that few human citizens could expect to do the same. Others question the presence of a seven-person crew doing daily care on the sprinkler system without proof that the toad is there or could ever safely return.

There is perhaps one positive outcome. Tanzania is still rich in biodiversity, and Kihansi has helped develop homegrown expertise to preserve it. The loan has helped Tanzanian and foreign scientists study the gorge together, plus train Tanzanian grad students, hire professors, and buy textbooks and computers. This has "played an important role in capacity-building for local scientists," says Henry Ndangalasi, a botanist at the University of Dar es Salaam. The nation is "mindful of the importance of scientific knowledge," says Sarunday. "The goal of Tanzania is to achieve economic prosperity and have a protected environment at the same time."

–KEVIN KRAJICK

Kevin Krajick is the author of *Barren Lands: An Epic Search for Diamonds in the North American Arctic*.



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CELL BIOLOGY

Great Balls of Fat

Lipid droplets, long-ignored globules inside cells, are earning recognition as possible organelles involved in cholesterol synthesis and much more

In the breast cells that produce milk, they're called milk fat globules. In plants, they go by the name oil bodies. In fruit flies, lipid storage droplets. Yeast, lipid particles. Cell biologist Richard Anderson prefers the name adiposomes. Immunologist Peter Weller baptized them eicosasomes.

Whatever their name, these intracellular blobs of triglycerides or cholesterol esters, encased in a thin phospholipid membrane, are catching the attention of more and more biologists. It turns out these lively balls of fat have as many potential roles within cells and tissues as they have names. Pockmarked with proteins with wide-ranging biochemical activities, they shuffle components around the cell, store energy in the form of neutral lipids, and possibly maintain the many membranes of the cell. The particles could also be involved in lipid diseases, diabetes, cardiovascular trouble, and liver problems.

This is a far cry from earlier perceptions of lipid droplets, the name most scientists use for the particles. Biologists once considered lipid droplets just inert storage vessels for energy-rich fats. Yet recent studies indicate that the cell keeps a tight rein on their function with molecules that regulate what the particles do, where they go, and what other cellular compartments they cavort with. And a new technique that allows better imaging of lipid droplets in live cells promises even more surprises.

"I've been in cell biology for more than 30 years, and lipid droplets have always been this bag of lipid," says Anderson, who conducts membrane research at the University of Texas Southwestern Medical Center in Dallas. "What is new is the focus on the droplet as an organelle."

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