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The principles of rapid response for amphibian conservation, using the programmes in Panama as an example

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As a direct response to many threats facing seriously threatened amphibian species, including habitat loss, pollution and, more recently, emerging infectious disease, *ex situ* captive-breeding programmes have proven valuable tools in species preservation. Uniting scientific research and conservation initiatives, here the growth of *ex situ* conservation for nearly a decade in central Panama is discussed. Looking at three specific projects, it can be demonstrated that collaborative efforts and multiple-response methods yield positive results in amphibian conservation and species preservation. At the same time, the lessons learned will be examined in each of these projects to allow for future amphibian conservation programmes to consider.

Key-words: amphibians; chytridiomycosis; conservation; *ex situ* breeding; Panama; rapid response.

INTRODUCTION

Amphibian declines in Central America were first noted in the 1980s with the loss of much of the amphibian community at Monte Verde, Costa Rica (Pounds *et al.*, 1997). At that time, scientists did not know of amphibian chytrid fungus *Batrachochytrium dendrobatidis* (or *Bd*) and, therefore, it was not sought in the declining populations. However, it has since been associated with subsequent mass mortality events occurring sequentially south-east through the Central American isthmus (Fig. 1; see Lips *et al.*, 2006). Project Golden Frog (PGF, http://www.projectgoldenfrog.org) was officially formed in 1999 in proactive response to what was perceived as the pending extinction of one of the world's most recognizable, culturally significant and Critically Endangered amphibians: the Panamanian golden frog *Atelopus zeteki* (Plate 1) (Zippel, 2002; IUCN, 2007). PGF became an international and multi-institutional initiative that has included primary partners at Círculo Herpetológico de Panamá, the Cleveland Zoo, the Columbus Zoo, the Denver Zoo, the Detroit Zoo, Lee University, the Maryland Zoo in Baltimore, Messiah College, the Smithsonian Tropical Research Institute and the Universidad de Panamá. At the onset of PGF, *Bd* was still well over 100 km to the west of the range of the Panamanian golden frog but all indications were that it was progressing south-eastward and eliminating (among others) species of montane bufonids in its path (e.g. *Atelopus* sp from Monte Verde, *Atelopus senex*, *Atelopus chiriquiensis*, *Atelopus varius* and the Golden toad *Bufo periglenes*). Because traditional *in situ* conservation measures, such as habitat protection, were ineffective against *Bd*, the decision was made to remove representative populations from the wild for *ex situ* management.

In September 2004, Dr Karen Lips from the University of Southern Illinois and her research team discovered the first *Bd*-positive sample, as well as small numbers of dead or dying amphibians in and around the streams in El Copé, Panama (Fig. 1). By December of the same year, hundreds of dead amphibians had been found and collected along the study transects. The suddenness and scale of the event were disturbing, even though declines

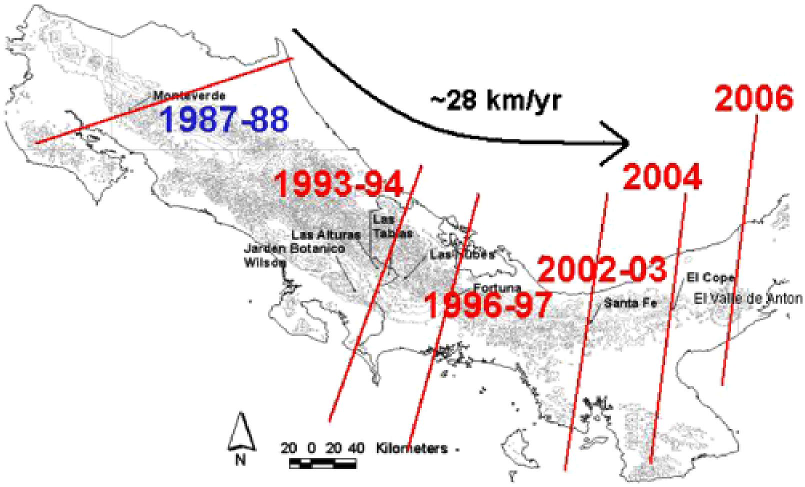

Fig. 1. Spatiotemporal spread of amphibian chytridiomycosis (caused by fungal pathogen *Batrachochytrium dendrobatidis*) in Costa Rica and Panama; figure modified and updated with new data presented herein from Fig. 1 in Lips et al., 2006.

Plate 1. Panamanian golden frog *Atelopus zeteki*. *Ron Gagliardo, Atlanta Botanical Garden*.

had been witnessed and studied in other locations in both Panama and Costa Rica for over a decade (Lips *et al*., 2005). In December 2004, there was a clear correlation between the sudden decline of an amphibian population and the first arrival of *Bd* at long-term study transects in central Panama (Lips *et al*., 2006). The transects within the Parque Nacional General de División Omar Torrijos Herrera, near the town of El Copé, were surveyed for over 4 years and declines were documented in local populations of most amphibians that were far above the fluctuations recorded before the arrival of *Bd* (Lips *et al*., 2006). The conclusion was that *c*. 50% of amphibian species and *c*. 80% of individuals may disappear in a short period of time.

These data instigated the call for a meeting of concerned scientists in Atlanta, Georgia, USA. The simple question ‘What can we do?’ provided the group with the challenge to take action, which led to the formation of the Amphibian Recovery and Conservation Coalition (ARCC) project. Similar to circumstances that initiated PGF, this group was faced with a challenge of attempting to ward off a major loss of biodiversity. What makes the ARCC project unique is the attempt to salvage multiple species during a ‘crash’ using triage techniques under less than ideal conditions. The drastic declines observed at El Copé were predicted in El Valle, possibly the last ‘upland’ area of reasonably undisturbed fauna and habitat of the Talamancan highlands region of eastern Costa Rica and western Panama, instigating the ARCC project, where individuals were exported because of a lack of facilities; however, simultaneously, the feasibility of performing this work in Panama was investigated. The El Valle Amphibian Conservation Center (EVACC) was created to provide an in-country *ex situ* facility in which assurance colonies of seriously threatened, regional endemics and other specifically selected species could be maintained long term until pertinent threats could be mitigated and the species could be reintroduced. *Batrachochytrium dendrobatidis* has travelled eastwards along the mountain range (Lips *et al*., 2006) and at the time of project initiation was only 50 km away.

The creation of the EVACC was a direct response to the need identified by PGF to breed golden frogs in Panama and to the political and logistical challenges encountered by ARCC who exported rescued amphibians because of the lack of suitable in-country facilities. Both these projects relied heavily on the political and logistical framework put in place by PGF. Initially, three goals were set. The first aimed to create and maintain an *ex situ* colony of Panamanian golden frogs in country. Many zoos, tourist destinations and hotels in central Panama use these frogs to attract visitors. This *ex situ* colony could be used to supply captive-born individuals for such displays, alleviating pressure on wild populations. The second goal was to house, display and breed amphibians rescued from El Copé and El Valle during the ARCC project. The third goal was to serve as an educational centre for the citizens of Panama, to learn about their native amphibian fauna. It must be noted that initially, the intention was that golden frogs would be returned to Panama to stock EVACC from PGF and other species from the ARCC, for project publicity purposes. Thus, most of the animals destined to be housed and displayed at EVACC would be returned from the United States.

Fifty *ex situ* specialists representing 14 countries and every amphibian-inhabited continent held a meeting in El Valle in February 2006 (Zippel *et al*., 2006) with a goal to discuss the approach that the eclectic assortment of zoos, aquariums, botanical gardens, academic institutions and private individuals could adopt to address *ex situ* aspects of the *Amphibian Conservation Action Plan* (ACAP: Gascon *et al*., 2007; Moore & Church, in press). As a direct result of this meeting, two things became immediately clear that would alter the course of EVACC. First, despite the original intention to do so, animals that had been exported from Panama, housed in the United States in less-stringent quarantine, should not be returned to Panama to prevent any risk of inadvertently introducing any novel pathogens. Second, with the large number of species requiring *ex situ* breeding action, it quickly became clear that EVACC would have to do more than breed Panamanian golden frogs and display a few other frog species. With this new mandate, the facilities' ultimate goals were now solidified. The primary objectives of EVACC are twofold. The first is to serve as a repository to prevent the extinction of the threatened amphibian species of El Valle and to use these populations as a source for reintroductions at the appropriate time in the future. The second is to foster appreciation and raise awareness of the amphibian fauna of El Valle through conservation education and research. This paper summarizes the work of PGF and ARCC that led to the creation of the first in-country facility in Panama for protection of significant amphibian biodiversity.

METHODOLOGY AND IMPLEMENTATION

Obtaining proper permitting licenses from the Panamanian agency in charge of the protection of natural flora and fauna in country (Autoridad Nacional del Ambiente, ANAM) and making important contacts, PGF initiated their project focusing on research in streams in central Panama. From 2001 to 2005, PGF established seven transects in streams to gather data on stream quality, as well as survey adult, metamorphosed froglets and tadpole populations in *A. zeteki*, and egg masses in streams. PGF used these data to establish Evolutionarily Significant Units (ESUs) of Panamanian golden frogs, revealing that the Panamanian golden frog actually spans two species: *A. zeteki* and *A. varius* (Zippel *et al*., 2007). The exportation of animals then began in 2001. In May of 2005, PGF sent a team down to Panama to collect their last group of golden frogs, animals possibly infected at the advanced *Bd* front and treated in the field.

ARCC began their project utilizing bureaucratic, logistical and personal relationships put in place by its predecessor, PGF. With Panamanian biologists, ARCC first secured the support and directive from the Panamanian government to collect and remove amphibians from harm's way. The project ran from 1 June to 1 September 2005 and utilized the skills of six staff and dozens of volunteers from around the world. The staff was responsible for arranging all logistics, fieldwork and the formidable task of diligent care of captive amphibians in makeshift facilities. These facilities were primarily rented houses or, in the case in El Valle, a duplex provided at no cost by the Hotel Campestre. Strict quarantine, treatment and maintenance protocols were established to help to maintain the best possible hygiene under the circumstances. Individual latex gloves were used to handle each individual, reducing the chances of cross-contamination between frogs. Enclosures were disinfected every other day using a 10% bleach solution. Only non-bleached paper towels were implemented for routine cleaning protocols. Each animal was swabbed for *Bd* testing using the polymerase chain reaction (PCR) method according to Annis *et al*. (2004) and assigned a group number and individual number corresponding to the species and site of collection. The date of collection, gender and the general physical appearance of each animal were recorded for management purposes. Water used for amphibians was simply rainwater collected in 95 litre containers with additional disinfection or filtration. Hand-collected and trapped food items were used to maintain amphibians during their in-country stay before being exported.

At El Copé, transects established previously by the Lips group were monitored. These transects produced very low numbers (60 total) of species and individuals during the course of the project and thus, all were collected, swabbed for subsequent PCR testing to detect *Bd* and prophylactically treated with Itraconazole according to the method of Nichols & Larimande (2000). Sampling for *Bd* was performed daily during the 11 day treatment regime. All PCR analyses were performed by M. Poore and M. Levy at North Carolina State University, USA.

At El Valle, staff worked to collect up to 40 individuals (20 ♂♂/20 ♀♀) of species that were prioritized using a prototype ranking protocol developed by Roberto Ibáñez. This protocol took into account the degree of endemism, threat status and range size in determining which species to collect. The taxonomy is that of the online reference *Amphibian Species of the World* (Frost, 2007). The major logistical challenge in El Valle was holding many individuals from multiple taxa with small numbers of staff. Collection at some points had to be suspended as the routine care of previously collected animals needed to be addressed.

At the suggestion of ANAM, animals collected by ARCC staff were exported to Atlanta Botanical Garden, Georgia, USA, where they underwent a 30 day quarantine period during which animals were monitored and treated (if necessary) for internal parasites and further acclimated to new surroundings. This was accomplished at three intervals with three sets of export permits. Post-quarantine, animals were distributed among maintenance facilities at the Atlanta Botanical Garden, Zoo Atlanta, Georgia, USA, and the Henry Vilas Zoo, Wisconsin, USA. Over time, animals were distributed to other institutions with the facilities, staff and commitment to maintain these species and participate in the project.

EVACC made use of many of the protocols put in place by the ARCC project. Owing to the large number of amphibian species in El Valle and the limited space at EVACC, a selection process was applied to all species in order to determine which species do indeed require *ex situ* conservation. The selection process was based on a Role Selection document generated from the EAZA (European Association of Zoos and Aquariums) Reptile, Amphibian and Invertebrate TAG (taxonomic

SPECIES	IUCN	PGF	ARCC	EVACC
Panamanian golden frog *Atelopus zeteki*	CR	X		X
Harlequin frog *Atelopus varius*	CR	X		
Rana de Corona *Anotheca spinosa*	NT		X	X
Ranita de Cristal *Cochranella albomaculata*	LC		X	
Ranita de Cristal *Cochranella granulosa*	LC		X	
Vicente's poison frog *Dendrobates vicentei*	DD		X	X
Gastrotheca cornuta	LC		X	X
Ecnomiohyla fimbrimembra	EN		X	X
Hyloscirtus palmeri	LC		X	X
Rana mususas *Eleutherodactylus museosus*	EN		X	X
Craugastor gollmeri	LC		X	
Eleutherodactylus pardalis	VU		X	
Craugastor bufoniformis	LC		X	X
Craugastor punctariolus	EN		X	X
Hylomantis lemur	DD		X	X
Colostethus flotator	LC		X	
Colostethus pratti	LC		X	
Craugastor tabasarae	CR			X
Hemiphractus fasciatus	NT			X
Hyloscirtus colymba	EN			X

Table 1. Priority taxa for each of the Panama projects. IUCN criteria: CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; DD, Data Deficient; LC, Least Concern (IUCN, 2007). PGF, Project Golden Frog; ARCC, Amphibian Recovery and Conservation Coalition; EVACC, El Valle Amphibian Conservation Center.

advisory group) and the selection criteria developed at the February 2006 meeting (Zippel *et al*., 2006). Thus, EVACC identified the species in Table 1 from El Valle as requiring *ex situ* conservation tactics. It was also decided that if presumed extinct amphibian species were suddenly rediscovered somewhere in the Panamanian Talamancan highlands, a captive colony would be established at EVACC from salvaged individuals.

In April 2006, an anuran from a stream inside the El Valle watershed tested positive for *Bd* by PCR. Until this point, construction of EVACC had been progressing slowly and housing amphibians at the facility was out of the question. A temporary facility was again established at the Hotel Campestre in El Valle. In May 2006, permits were granted from ANAM and collection of select amphibian species began. Upon entering the collection, each specimen was identified to the species, sexed, weighed (in grams), snout–vent length was measured (using dial calipers in mm) and swabbed for subsequent *Bd* testing. Individuals were then immediately entered into a prophylactic treatment course for chytrid fungus infection using the method based on Nichols & Larimande (2000). Each specimen was carefully cataloged to track feeding, defaecation history (for retrospective analysis of gut parasites and diet) and all medical treatments. Once animals completed their treatment course, they were re-weighed, examined, re-swabbed and usually transferred to a clean room unless under special medical circumstances. Individuals were fed daily or every other day depending on the species, and enclosures and substrates were cleaned and disinfected with 10% sodium hypochlorite (bleach) on the days between feedings. This allowed workers to monitor fresh faecal material and uneaten food items as well as to maintain maximum hygiene standards. Water used for the amphibians was potable tap water run through a $0 \cdot 5\ \mu m$ carbon block filter to remove any chlorine, pesticides or other harmful substances (after the water was filtered, it was stored in a 95 litre bucket in the bathroom of each room).

Strict quarantine protocols were also imposed, namely dedicated, disinfected footwear was used for each person entering each room and equipment was not transferred between rooms. A pair of disposable, powder-free, vinyl gloves was used for every individual enclosure for a single use. All discarded enclosure refuse, used gloves and collection material were disinfected with 10% sodium hypochlorite before it was discarded as trash to prevent the spread of any pathogens from the collection. The floors of both rooms and the immediate area outside the rooms were mopped daily with 10% sodium hypochlorite.

At first, providing adequate quantities of the appropriate food proved to be a challenge. Daily collection of wild invertebrates and meticulous note taking on the preferences of the species allowed for an adaptive approach to arriving at the correct type of food and quantity. Techniques for invertebrate collection ranged from sweep nets, attractant lights and hand collecting to ingenious devices involving circular fluorescent lights and an extractor fan. More recently, colonies of Domestic crickets *Acheta domestica* obtained from a source within Panama have been set up to produce an adequate supply for feeding the collection. Two species of Fruit fly *Drosophila melanogastor* and *Drosophila hydei*, and Springtails *Collembela* sp were imported from the United States and are being cultured on site. Collection of larger insects is still necessary for large anurans but plans are in place to culture these species.

In March 2007, the first amphibians were transferred from the hotel to the EVACC facility. Correct water management was necessary to ensure that chytrid-free animals are not reinfected by source water and that parasite and other micro-organisms are not transferred between enclosures. The source water at EVACC was filtered in several stages, the last of which excluded any organism larger than $0 \cdot 5\,\mu m$. Once water has left an enclosure, it is taken directly to a drain. The ends of the waste lines are fitted with strainers and check valves to prevent both water and potential disease vectors (flushed feeder insects, etc.) from entering the ecosystem. Individuals have been monitored for parasites during the course of their time in captivity.

RESULTS

PGF secured *ex situ* populations of three ESUs of Panamanian golden frogs, thereby preventing their outright extinction. From 2001 to 2005, 111 animals were collected, including 26 amplectant pairs and 59 newly metamorphosed froglets. These individuals were exported to zoos in Detroit, Baltimore and Cleveland for initial quarantine and maintenance. At the time of writing, 41 of the wild-caught animals are represented with over 1500 animals in the captive-bred population at nearly 50 Association of Zoos and Aquariums (AZA) institutions. *Batrachochytrium dendrobatidis* is currently sweeping through the eastern-most extent of the Panamanian golden frog range and extinction in the wild seems imminent. Although PGF intends to continue its programmes in research, outreach and captive management, focus will be broadened to support conservation work with other species in the Critically Endangered genus through an initiative called the Atelopus Conservation Trust (see http://www.projectgoldenfrog.org).

ARCC collected only about 60 individuals from the El Copé site. The taxa in greatest numbers included centrolenid and leptodactylid frogs. The findings in El Valle were much more productive because *Bd* had not yet arrived. Hundreds of individuals in total from nearly 30 species were collected (Table 1). Not all individuals encountered were collected as once 20 of each sex were obtained, duplicates were released.

In captivity, some species, such as *Hyloscirtus palmeri* and *Hemiphractus fasciatus* (Plate 2), proved extremely difficult to maintain either in Panama or Atlanta. Several species are actively breeding, however, including *Hylomantis lemur*, *Colostethus pratti*, *Eleutherodactylus gaigae*, *Gastrotheca cornuta* (Plate 3), *Anotheca spinosa*, *Dendrobates vicentei* and *Minyobates minutus*. In some cases, these breeding events, some taking place within temporary ARCC triage or EVACC quarantine facilities, represent the first in captivity. Environmental factors, such as extreme barometric fluctuations, local food items or even regular disturbance from enclosure cleaning, were possible triggers. In *Hy. lemur*, hundreds of F1 offspring produced in Atlanta have been dispersed to over 15 facilities in three countries, increasing the *ex situ* safety net for this particular species. Offspring of the Rocket frog *C. pratti* have also been distributed. Other taxa, such as the Marsupial frog *G. cornuta*, despite several

Plate 2. Casque-headed frog *Hemiphractus fasciatus*. *Edgardo Griffith, El Valle Amphibian Conservation Center*.

Plate 3. Horned marsupial frog *Gastrotheca cornuta*. **Gravid ♀ with eggs in pouch.** *Ron Gagliardo, Atlanta Botanical Garden*.

successful breeding events, have proved difficult in terms of raising juveniles to adulthood owing to nutritional issues. This indicates that there is still much to learn about the captive care of many species.

For the EVACC project, it is still too early to declare success or failure. Measurable achievements of the project are simple and primarily concerned with our ability to keep the individuals alive (short term), reproduce them (medium term) and overcome any issues relating to captive management, such as dietary and habitat needs and ability to produce F2s (long term). *Anotheca spinosa*, *Pristimantis diastema*, *G. cornuta*, *He. fasciatus* and *Hy. lemur* have been successfully reproduced so far and dozens of captive-bred amphibians exist as a result. Some priority taxa are yet to breed, some are yet to be collected and it may turn out to be too late for those species. Amphibians that have died have been submitted for comprehensive necropsy to Dr Allan Pessier at the San Diego Zoological Society. Preliminary necropsy results are suggestive of malnutrition likely associated with captive diets as a significant source of mortality along with lungworm infections. Finally, after taking a step back, it is important to remember that through the transfer of skills related to amphibian husbandry for the first time, there is a building in Panama where a skilled staff cares for and reproduces threatened Panamanian amphibians.

CRITICISMS OF THESE PROJECTS WITH RECOMMENDATIONS FOR SIMILAR PROJECTS

At the time PGF was removing animals from the wild, no facilities existed in Panama to manage the animals within their range country. The same conditions still existed several years later at the inception of the ARCC project. Thus, in both cases, the animals were exported to the United States. This has created several complications that could have been avoided had the animals been kept in the range country. The planning and construction of EVACC addressed many of these issues.

Biosecurity

In moving animals across vast geographical barriers, the risk of exposing naïve populations to new pathogens is elevated. The problems of exposing imported species to potential pathogens in existing collections are only surpassed by the potential of native species to succumb to novel exotic pathogens brought in by wild collected animals. If animals must be removed from their range countries, appropriate biosecurity measures should be put in place to protect both the captive and the nearby wild populations. If the Panamanian animals in the United States are ever to be returned to the wild, it will be the responsibility of the institutions involved to do everything in their power to study the pathogens present in the candidate animals. The institutions must determine whether the pathogens came in with the original founders or whether they were subsequently introduced and must therefore be eliminated before release. Of course, one can only test for those pathogens that are already known, and a significant risk remains in introducing unknown, undetectable pathogens. Controlled laboratory exposure experiments should also be carried out to test for any negative impacts of introduced amphibians on the remaining wild amphibian populations. Most of these complications could have been avoided had the animals remained in Panama. Captive amphibian populations would benefit if more could be understood about long-term effects or artefacts of simply being raised under controlled captive conditions and subsequent issues when these animals are repatriated. For now, the recommendation is that any rescue colonies, anywhere in the world, remain within the range country. This will reduce stress on animals and eliminate risks of disease transmission across international borders. Working at the hotel in Panama presented some unique challenges with respect to biosecurity; for example, staff found native Marine toads *Rhinella marina* inside the 'clean' (post-chytrid treatment) room. Marine toads are known carriers of *Bd* (Berger *et al.*, 1998) and the results of swabs taken from toads that were able to gain access to the rooms are eagerly anticipated. Toad faeces were also found on top of enclosures. This obviously has implications for the spread of parasites.

Politics

It is often time-consuming and expensive to obtain the necessary permits to remove animals from the wild. Trying to move animals across international borders adds another layer of complexity and expense to the process. In addition, regardless of the exporter's motives, scientific reasoning and government support, removing animals from their country of origin can have negative publicity implications (Fig. 2). Gathering host-country national support in areas where the projects are being carried out is also helpful. Finally, one must consider how the 'internal' regulations of zoological associations, wildlife agencies and agriculture departments can affect (negatively or positively) the overall conservation mission of a programme. Are we keeping the best interest of the species in mind?

Resources and funding

In addition to biosecurity and permitting expenses, there are other financial incentives to keep programmes in range countries. The materials and labour to construct facilities can be cheaper outside the United States, and because of cost-of-living differences, biologists can be trained and used for less. Labour may be less expensive in some parts of the world but we must consider the amount of materials purchased outside of host countries and shipped in for these projects. This will increase costs beyond normal levels; we may quickly lose the ability to generalize about where projects are less expensive to implement. The situation in Panama is likely to be different from other countries. The availability of almost any material needed for construction and Panama's use of the US dollar as its currency certainly had a positive effect on logistics. One key point to consider here is that the funding necessary to begin and implement a project is only the beginning and in the case of ARCC, funding was sometimes sporadic, resulting in some minor delays with parts of the project. Owing to the rapid response needed and accelerated timelines, it was difficult to put all funding in place before beginning the project. EVACC started with a very modest budget and very modest goals. During the course of the project both were allowed to grow. In contrast to

Fig. 2. Clipping from Panamanian newspaper showing 'mixed emotions' of having their animals exported. *Usted Decide*, **11 September 2006.**

the ARCC, a gradually changing budget likely worked better under these circumstances because of the nature of the project. If the budget had been tightly restricted and not been allowed to grow to match the changing goals of the project, it may well have failed.

Capacity

While the United States might have more expertise and physical space for managing amphibians, their capacity is still quite limited. In 2000, a survey of AZA institutions revealed 'only enough space . . . to accommodate 10 taxa of amphibians' (K. Wright, pers. comm.). Clearly, the AZA community cannot lead many such rescues before their capacity is exceeded. If additional capacity must be built, better to build it where it is needed, train host-country nationals to run it and plan to support operations in country. Some of these were specific hurdles in the ARCC and EVACC programmes as staff did not have the advantages of easy access to resources, such as ordering of food items or immediate access to veterinary facilities. Co-ordination of these activities in country is sometimes made more difficult by host-country regulations; for example, importing domestic crickets (a common food item for captive amphibians) has proven very difficult. Collection of wild native food was a large drain on manpower, although the nature of this type of response to a biodiversity crisis excludes the possibility of establishing invertebrate food cultures well ahead of time. This is something that should be established as rapidly as possible once the need is identified. At EVACC, manpower, through staff and volunteers, was gradually increased as the number of amphibians in captivity grew. A period of time did exist where staffing level was inadequate. Establishing an appropriate quantity of staff in advance of the need, so that training can be provided under less stressful conditions, is suggested. All three projects involved some bilingual staff and volunteers, but there were still instances where the lack of language proficiency created delays or hurdles. Specific issues regarding facility design and the project objectives are numerous and potential solutions for future efforts are provided by Pfaff & Crump (2007).

In addition to the specifics of capacity issues, there is a more philosophical issue to consider. This is the concept of institutional commitment. The individuals taken in by all three projects need careful stewarding that takes not only individual commitments from keepers and organizers but also institutional commitments by various partners. Individual zoo staff members might come and go, but programmes that involve the preservation of species need to continue seamlessly; this requires unwavering institutional commitment. How long will PGF, ARCC and EVACC be supported by organizations?

CONCLUSIONS

With amphibians facing more threats and challenges than ever, careful choices must be made in order to preserve as much biodiversity as possible. The problems of amphibians are likely to increase in the future, along with the urgency of the response required. In too many cases, *ex situ* breeding work may be the only short-term solution for taxa that may otherwise disappear. This is an opportunity for academic researchers and zoological institutions to work together in synergy. Whether removing animals for research or as part of a rescue operation, full consideration must be given to the consequences. This work must be carried out carefully, with adequate planning and forethought. Thus, there are several principles of rapid-response programmes: being clear of the overall goals of the project, establishing the infrastructure including administration and operations to properly channel the resources needed to implement and maintain it and defining protocols for implementation and operation before initiating the programme. Embedded in these principles are more specific aspects including the procurement of funding, securing government support and assembling the proper staff (from team leaders to veterinarians). Once these actions are taken, another part of the process comes into play for implementation including species prioritization, establishing local staff and agencies to take part, confirming funding and finally, beginning physical collections and triage.

As zoological, academic and private stakeholders transform into conservation stewards and become more active in these types of projects, action must follow a clear understanding of the commitments required. Following the recommendations proposed by the Amphibian Ark (http://www.AmphibianArk.org; Zippel *et al*., 2006) and ACAP (Moore & Church, in press) as a guide and keeping long-term goals in mind along the way, these types of programmes could succeed. There are many ways to accomplish the overall goal of species preservation and using accepted protocols of biosecurity, handling as much of the work in range country and making the commitments necessary to carry the projects through to completion will ultimately be very important considerations for long-term survival of some of our most threatened species.

PRODUCTS MENTIONED IN THE TEXT

Itraconazole: supplied by PCCA Inc., Houston, TX, USA.

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