Herpetological Conservation and Biology 6(3):340–352.
Submitted: 6 May 2011; Accepted: 16 August 2011; Published: 31 December 2011.

THE AMPHIBIAN ARK: A GLOBAL COMMUNITY FOR *EX SITU* CONSERVATION OF AMPHIBIANS

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***Abstract.*—The Amphibian Ark (AArk) was launched in 2006 to unite and expand the global but disjunct community of amphibian *ex situ* conservationists. The impetus was to help that community implement the *ex situ* components of the Amphibian Conservation Action Plan (ACAP), primarily the rescue and management of those amphibian species that cannot currently be safeguarded *in situ*. Building a foundation for AArk partners around the world to act, the AArk officers have aimed to: (1) liberate new funds by raising public awareness through the *2008 Year of the Frog* campaign; (2) identify conservation actions for species in need (38% of all amphibian species have been assessed to date); (3) train keepers to manage *ex situ* populations (> 1600 students trained); (4) provide guidelines for best management practices; (5) facilitate the formation of partnerships to sustain rescue programs for their duration; and (6) support other ACAP partners because program success is defined as mitigating *in situ* threats and, if necessary, reintroducing rescued species as soon as possible. Nearly 100 priority rescue species are already in developing *ex situ* programs, with over half of these programs initiated since the ACAP. A discussion of AArk activities is preceded by considering a number of essential prerequisite issues that profoundly affect AArk structure and values, including whether *ex situ* programs are necessary and effective, what challenges and risks they introduce, and what unique resources the *ex situ* conservation community offers.**

Key Words.—ACAP; amphibian; conservation; *ex situ*, zoo

BACKGROUND

***The problem and the plan.*—**Amphibians are in great danger. As many as 159 species are believed recently extinct, nearly one third of remaining species are currently threatened with extinction, and one fourth are so poorly known that they can only be called 'Data Deficient' (IUCN, Conservation International, and NatureServe 2011). The only other vertebrate groups as well assessed as amphibians are birds and mammals: at least 30% of amphibian species are threatened compared to 21% in mammals and 12.5% in birds (IUCN, Conservation International, and NatureServe. 2011). Moreover, with estimates of an additional 6,000 undiscovered amphibian species so rare as to have avoided detection to date (Parra et al. 2007), the potential losses in this single clade are staggering. Perhaps more sobering than the number of species affected is the rate at which they are disappearing: two independent studies calculated a background extinction rate of amphibians now hundreds or thousands of times higher than historic levels (McCallum 2007; Roelants et al. 2007). This crisis represents the greatest known extinction event in the history of amphibians, and, perhaps, the greatest taxon-specific conservation challenge in the history of humanity.

A growing faction in the scientific community recognized and declared that it is "morally irresponsible" to merely document this extinction crisis (e.g., Gascon et al. 2007), and so the 2005 Amphibian Conservation Summit followed the original 2004 Global Amphibian Assessment, leading to production of an Amphibian Conservation Action Plan (ACAP; Gascon et al. 2007). The ACAP identified actions required to better understand and counter the global amphibian extinction crisis. An Amphibian Survival Alliance was called for to oversee implementation of the ACAP (Mendelson et al. 2006), and the Amphibian Ark (AArk) formed to unite the *ex situ* conservation community and address the captive components of the ACAP (Pavajeau et al. 2008). A discussion of AArk activities is best preceded by considering a number of issues, including whether captive programs are necessary and effective, what challenges and risks they introduce, and what unique resources the *ex situ* conservation community offers.

***What is the* ex situ *conservation community?*—**While *in situ* refers to the context of an organism in the wild, *ex situ* refers to the context of its being captive. The '*ex* *situ* conservation community' is a global network of individuals and organizations working with living organisms in captivity with the intent to help preserve those species in the wild. For amphibians, this community comprises primarily zoos and aquariums, but other partners can play significant roles. For example, we have found that there are more Wyoming Toads (*Anaxyrus baxteri*; IUCN Extinct in the Wild) in government facilities, more Chinese Giant Salamanders (*Andrias davidianus*; IUCN Critically Endangered) in the commercial sector, more Cuban Long-Nosed Toads (*Peltophryne longinasus*; IUCN Endangered) in museums, more Seychelles Frogs (Sooglossidae; all IUCN Vulnerable) at Non Governmental Oganizations (NGOs), more Southern Corroboree Frogs (*Pseudophryne corroboree*; IUCN Critically Endangered) in a privately run facility, and more Quito Rocket Frogs (*Colostethus jacobuspetersi*; IUCN Critically Endangered) in universities than in zoos. Anyone working with captive organisms to help conserve those in the wild is part of this community, but for most amphibians, zoos are the primary players.

Justification: Are* ex situ *programs necessary?—The threats amphibians face are diverse, poorly understood, sometimes synergistic, and almost entirely anthropogenic. Most threats are under direct control and could, in principle, be mitigated in time to prevent further extinctions. For example, the most common threat to amphibians is habitat loss (Stuart et al. 2004), and the primary cause of habitat loss is industrial agriculture. Amphibian species facing such threats can, and should be, saved in the wild: in these cases through identification and protection of key habitats.

Other threats are not currently mitigable or probably will not be mitigated in time to prevent additional extinctions. For example, the emergent infectious disease chytridiomycosis, caused by the fungus *Batrachochytrium dendrobatidis* (*Bd*), has already affected hundreds of species and has spread to every continent where amphibians are found (Fisher et al. 2009). Although research on probiotics (Harris et al. 2009), acquired immunity (Richmond et al. 2009; but see Stice and Briggs 2010), and other means of conferring disease resistance suggest some hope, there is no immediate means of eliminating *Bd* or mitigating its effects in the wild. Consequently, even if the will existed to mitigate all the threats under direct control, hundreds of species would still face probable decline and possible extinction in the wild. The AArk focuses on those species that cannot currently be safeguarded *in situ*. It is not an endeavor of choice: the AArk's position is that species conservation is defined as securing the future of the species in the wild. As such, rescuing species into captivity is a measure of last resort, a failure of *in situ* action, albeit one that can sometimes be reversed. Conservation stewards in this case are being forced to use captive rescue as a temporary means to buy time for further research and development of applied methods of threat mitigation.

Exactly how many species require *ex situ* rescue is not yet clear. Although there are some species that have faced extinction from imminent habitat destruction (e.g., Kihansi Spray Toad [*Nectophrynoides asperginis*], Krajick 2006), climate change (Raxworthy et al. 2008; neotropical salamanders, Rovito et al. 2009), introduced species (e.g., Mallorcan Midwife Toad [*Alytes muletensis*], Moore et al. 2004), and over-collection (e.g., Lao newt [*Laotriton laoensis*], Stuart et al. 2006). *Chytridiomycosis* is the threat associated with most of the recent extinctions and estimates suggest that this disease has already affected more than 350 species and has caused the decline or extinction of about 200 of these (Skerratt et al. 2007; Fisher et al. 2009). Bielby et al. (2008) analyzed attributes of species biology and habitat, and predicted that at least 837 species of anuran are expected to rapidly decline with "genuine extinction risk" in the event of *Bd* infection. Rödder et al. (2009) used climate data to predict the potential global distribution of *Bd* and then compared that to known amphibian distributions, concluding that 1,100 species of amphibian have ranges that overlap 100% with habitat predicted to be suitable for *Bd*. Ongoing AArk analyses (see assessment workshops, below), so far covering 1,356 of the 3,532 IUCN threatened and Data Deficient species, suggest that 362 (26.7%) of the assessed species require rescue or supplementation programs. Although threats and required conservation actions are different in every country, if we extrapolate these initial results to a global scale for all threatened and Data Deficient species (0.267 x 3,532), we would get a rough estimate of 943 species that would require captive assurance populations. By comparison, an estimate of the current global capacity for managing viable captive amphibian populations is only 50 species, at best (Zippel et al. 2008). Clearly, expansion of *ex situ* conservation management programs is desperately needed.

Justification: Can* ex situ *programs contribute to conservation?—*Ex situ* programs undoubtedly have prevented the extinction of species and resulted in successful reintroduction to the wild. There is no complete list of species that have been rescued from extinction through captive management; however, at the time of this writing there are 64 species (33 animals, 31 plants) classified by the IUCN as Extinct in the Wild (IUCN, Conservation International, and NatureServe. 2011) that would otherwise be Extinct if not for their presence in captive programs. Moreover, there is a handful of species once classified as Extinct in the Wild but later successfully re-established thanks to efforts including captive management (e.g., Arabian Oryx [*Oryx* *leucoryx*], Black-footed Ferret [*Mustela nigripes*], California Condor [*Gymnogyps californianus*], European Bison [*Bison bonasus*], Przewalski Horse [*Equus ferus*], Red Wolf [*Canis rufus*]; Maas, P.H.J. 2011. Last stand in captivity or cultivation: successes and failures. Available from http://www.petermaas.nl/extinct [Accessed 10 December 2011]), and a few that are technically still classified Extinct in the Wild but are part of reintroduction programs that have shown some success (e.g., Guam Rail [*Gallirallus owstoni*], Pere David Deer [*Elaphurus davidianus*], Socorro Isopod [*Thermosphaeroma thermophilum*], Wyoming Toad [*Anaxyrus baxteri*]; Maas 2011, *op. cit.*). Additionally, there are numerous species that have benefited from captive programs, including some that were brought back from being nearly Extinct (e.g., the Puerto Rican Crested Toad [*Peltophryne lemur*], Johnson 1999) and others that were re-established in parts of their former range from which they had been extirpated (e.g., the Mallorcan Midwife Toad [*Alytes muletensis*], Buley and Garcia 1997). Amphibian reintroduction programs are more often successful than not (20successful:11unsuccessful, Germano and Bishop 2008; 21:3, Griffiths and Pavajeau 2008), whether they involve *ex situ* efforts (14:3), or just wild-wild translocations (7:0; Griffiths and Pavajeau 2008).

In addition to managing threatened species for eventual release, *ex situ* programs can contribute to conservation in several other ways (Zippel et al. 2008). Conservation education, advocacy, and fundraising are explored below in the section on AArk activities. Research is another area where zoo collections make significant contributions (Murphy 2007); for example, teams including zoo biologists discovered the amphibian chytrid fungus (Berger et al. 1998; Longcore et al. 1998), described it as a new species (Longcore et al. 1999), and devised a treatment for captive amphibians (Nichols and Lamirande 2000). Finally, *ex situ* programs can contribute to conservation by producing surplus captive-bred animals for sale, simultaneously generating conservation funds while undermining trade in wild animals, although this is a contentious issue within the *ex situ* community (see http://www.amphibianark.org/resources/commercial-activities/).

Justification: Does* ex situ *conservation divert limited resources?—One could argue that *ex situ* programs divert limited resources away from more important *in situ* efforts (e.g., Snyder et al. 1996). This, however, is becomingly an increasingly gray area as zoos, a primary player in the *ex situ* community, become increasingly focused on *in situ* work. Zoos believe that *in situ* work is indeed more important than *ex situ* and that they must "increasingly commit to conservation in the wild as their primary goal and focus" or "be left behind by the conservation movement" (WAZA 2005). Indeed, zoos are investing more than ever in *in situ* work, with the collective contribution from the entire zoo community surpassing that of most 'traditional' *in situ* partners (Gusset and Dick 2010). Moreover, zoos rely heavily upon resources not otherwise available to traditional *in situ* partners, specifically, visitor admission fees. In essence, zoos re-route significant public resources that would not otherwise be available to *in situ* partners. In addition to direct support, the zoo budget portion that supports *ex situ* operations can be tallied and presented as 'matching funds' to leverage support for other aspects of integrated programs, including *in situ* work. These are some of the ways the AArk community helps other ACAP partners.

Justification: The challenges and risks of* ex situ *management.—There are a number of challenges and significant risks associated with managing *ex situ* populations. Populations kept in captivity across multiple generations risk losing genetic diversity, producing deleterious allele combinations, and undergoing artificial selection for maladaptive traits. Amphibians are not immune to these risks (Waldman and McKinnon 1993; Kraaijeveld-Smit et al. 2006; Allentoft et al. 2010); the AArk attempts to help its partners minimize these risks by providing population management guidelines (see AArk activities below).

Furthermore, a population kept outside its native range, as is common in the *ex situ* community, presents a considerable risk of transferring novel pathogens (or the amphibians themselves) into the local environment. The more or greater biogeographic barriers crossed (presumably indicative of historic isolation), the greater the risk (Zippel et al. 2008). The potential perils cannot be overstated: this scenario of improperly handled exotic animals accounts for all four proposed novel pathogen hypotheses regarding the origin and spread of *Bd* and the resultant destruction it has caused (Weldon et al. 2004; Garner et al. 2006; Goka et al. 2009; Farrer et al. 2011). Consequently, there is a new movement among responsible partners to sanitize wastewater from exotic collections and to take other steps to prevent animals and pathogens from escaping (Zippel et al. 2006; Fisher and Garner 2007; Robertson et al. 2008; Pessier and Mendelson 2010). Australian zoos have eliminated further exposure to this risk with an informal voluntary agreement not to import any exotic amphibians, while also focusing on the native threatened amphibians within each state. The AArk highly endorses the practice of working with species within their native range, or if they must be exported, to practice safe husbandry (see Pessier and Mendelson 2010 for best practice biosecurity guidelines).

Removing living organisms from their native range creates additional concerns beyond biosecurity (Gagliardo et al. 2008; Zippel et al. 2008). There are political implications with undertones of imperialism, especially when local authorities are capable but lack the resources. This situation is especially ironic given that the vast majority of threatened amphibians are found in tropical developing countries, where equivalent resources would provide greater returns due to lower costs of construction, supplies, and labor. For example, when contemplating rescues in Panama, the Houston Zoo wisely realized that the salary of one US keeper could provide income to 5.5 Panamanian keepers rescuing 5.5 times as many species in Panama. Finally, bringing exotic species back to zoos in developed countries for conservation management is, at best, a limited endeavor as it only diminishes the capacity of the receiving institution to manage its own native species. To quote Gagliardo et al. (2008): "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", an approach consistent with guidelines of the IUCN (2002) and the Secretariat of the Convention on Biological Diversity (2001).

When living organisms are held in cosmopolitan collections, as is nearly universal in the *ex situ* community, there is a considerable risk of cross-contamination with novel pathogens. When some of the organisms are then used for release, this risk can be great with consequences as severe as inadvertently releasing exotic organisms/pathogens into local environments. Pre-release screening can sometimes detect novel pathogens in prospective releases, and when numbers are abundant, those cohorts can be eliminated from the reintroduction population (Daly et al. 2008; Michael McFadden unpubl. data). However, when all remaining captive populations are affected, extensive and expensive 'challenge studies' must be planned in captivity to test the potential impact of these new pathogens on representatives of remaining amphibian species at the release site (e.g., Kihansi Spray Toad [*Nectophrynoides asperginis*] program, Allan Pessier, pers. com.). While pre-release screening can sometimes reveal risks, screening does not detect all pathogens sought (false negatives) or rarely those outside the scope of the tests. In at least one case, a new pathogen went undetected in pre-release screening and was introduced into a naïve environment (Walker et al. 2008). The AArk highly recommends that all organisms intended for release are maintained as near to their range as possible and isolated from allopatric populations (see Pessier and Mendelson 2010 for best practice guidelines).

The final challenge presented here regarding *ex situ* programs relates to ensuring that all programs are adequately supported for their duration. Establishing facilities and collecting rescue populations is only the first, albeit perhaps the single greatest, expense. However, it is insufficient to support only those first-year expenses without operational support for the long term, which may amount to years or more likely decades. In addition to financial planning, *ex situ* programs should consider it mandatory to establish at the onset a plan for working with research and resource management partners to mitigate threats in the wild and, if necessary, getting organisms back into the wild as soon as possible in the form of monitored, self-sustaining populations. For organisms that cannot quickly be placed back in the wild through reintroduction programs, an interim system that involves genetic management and distribution of progeny as a safeguard to losing them at one facility should be considered.

The unique qualifications of the ex situ conservation community.—Fortunately, a robust community of *ex situ* conservationists with considerable resources already existed prior to the AArk. There are approx.1,300 zoos worldwide employing over 100,000 people and spending $350 million USD on wildlife conservation each year under the umbrella of the World Association of Zoos and Aquariums and the national/regional zoo associations (Gusset and Dick 2010). These institutions currently hold at least 40,000 individual amphibians (L. Bingaman Lackey, pers. comm.), and this number is surely an underestimate as the International Species Information System (ISIS) does not tally group-accessioned animals, and some institutions do not report to ISIS. In addition to their potential capacity to manage amphibians, these institutions also hold amazing potential to raise awareness among the general public through their greater than 1,000 websites and > 700 million visitors per year. Beyond zoos, other organizations participate in *ex situ* conservation of amphibians (including aquariums, botanical gardens, natural history museums, nature centers, universities, government agencies, NGOs, and the private sector); in fact, some of these non-zoo partners might be the primary drivers of reintroduction programs (Beck et al. 1994). No other community was as pre-adapted as zoos and partners to globally address the *ex situ* components of the ACAP. What the amphibian *ex situ* conservation community lacked and the AArk has aimed to provide was global unity, an awareness and funding campaign to create new dedicated funds, and a jump-start on capacity building, especially in developing countries.

LAUNCH OF THE AMPHIBIAN ARK

The AArk was founded in 2006 by members of its three parent organizations: the IUCN/Species Survival Commission (SSC) Conservation Breeding Specialist Group, the IUCN/SSC Amphibian Specialist Group, and the World Association of Zoos and Aquariums. Its mission is to ensure the global survival of amphibians, focusing on those that cannot currently be safeguarded in nature. The AArk is not the small handful of 'employees' or its Steering Committee. It is the entire global community of partners managing rescued amphibian populations, as well as those conducting conservation research, fundraising, lobbying policy makers for change (or simply raising public awareness), all to the same end. Of course, that community has existed for decades and the AArk founders simply erected the AArk umbrella above it to give it a single name and face with which partners, governments, donors, and the general public can identify, as well as provide a means for global coordination and development. (See http://www.amphibianark.org/aark organization.htm for organizational details.)

***Activities of the Amphibian Ark.*—**AArk activities can be divided into three general categories: (1) raising awareness and funds; (2) building capacity for *ex situ* response; and (3) supporting ACAP partners.

Raising awareness and funds.—In 2008, the AArk conceived and led a publicity campaign called the *Year of the Frog* (YOTF), modeled after the European Association of Zoos and Aquaria's (EAZA) annual campaigns, and was elevated to the first unified campaign of the global zoo community. Information packs were produced for AArk partners to use in visitor education and are available at http://www.amphibianark.org/pdf/YOTF/YOTF.pdf. Sir David Attenborough served as the campaign patron, speaking at several functions and creating a program in his *Life in Cold Blood* series dedicated to amphibian biology and conservation. Jeff Corwin also helped promote amphibian conservation on behalf of AArk by recording a number of public service announcements (PSAs) for YouTube, appearing on the Ellen DeGeneres Show, and completing a documentary with Animal Planet called *The Vanishing Frog*. Jean-Michel Cousteau similarly recorded a PSA for YouTube and helped the AArk develop a partnership with the US National Association of Biology Teachers. Jane Goodall included messages about amphibian conservation in her Australia-based lecture circuit on behalf of AArk. Disney's Kermit the Frog appeared with AArk executives in Washington D.C., USA, to raise awareness among policy makers, flew on the 122nd flight of the Space Shuttle for campaign awareness, and recorded a PSA with Disney celebrity Selena Gomez. European AArk partners secured the assistance of two princesses (Princess Xenia of Saxony and Victoria, Crown Princess of Sweden) for media events, playing on the princess/frog fairy tale. The Clorox Company signed on as a corporate sponsor, funding the planning of the YOTF campaign, Corwin's documentary, and the completion of the public exhibit at the El Valle Amphibian Conservation Center in Panama, as well as donating free product to ACAP partners (to minimize *Bd* transmission) and launching a website to promote their role (http://www.fightforthefrogs.com). AArk partners tallied thousands of news stories by the third quarter of 2008 and estimated an advertising equivalent value of approx. one million USD.

People around the world were moved into action by the campaign. Many smaller businesses and private individuals (of all ages), along with zoos and aquariums worldwide, generated hundreds of thousands of dollars for the campaign in novel ways, including donations in lieu of wedding and birthday gifts, repelling down bridges, holding spaghetti dinners and wine events, raffling handmade quilts and hand-knitted frog sweaters, and making other frog-related items for sale. (More about these efforts can be found at http://www.amphibianark.org/howyouhavehelped.htm). Students and teachers from a number of countries raised over USD $4,400 through coin drives, raffles, craft fairs, bake sales, t-shirt sales, and a variety of other fundraising efforts. One school in particular (Tremont Elementary School, Upper Arlington, Ohio, USA) has continued its fundraising efforts beyond 2008 and has been able to fundraise over USD $5,400 to date.

These efforts bore fruit. While the YOTF campaign did not reach the multimillion-dollar levels needed to save hundreds of species (Gascon et al. 2007), it did bring the needs of the amphibian conservation community to the forefront and raised modest funds to get things moving in a positive direction. In 2008, AArk partners spent $4.4 million (all funds listed in USD) on *ex situ* programs (vs. $2.9 million in 2007) with another $12.1 million pledged over the following five years, and $868,000 on *in situ* programs (vs. $462,000 in 2007) with another $2.1 million pledged over the following five years. To support the campaign, core operations, and workshops, the AArk central office collected over $350,000, predominately as a result of the very successful capital campaign led by European AArk partners in EAZA.

Carrying the momentum of publicity forward beyond 2008, AArk created a free membership program through which members receive a quarterly newsletter to update them on major developments in amphibian conservation. The AArk membership webpage can be found at http://www.amphibianark.org/membership.htm. Currently, approx. 6,000 members have subscribed to the AArk newsletter, and this number continues to grow.

Building capacity for ex situ *response.*—To build a proper foundation for rescuing and managing imperiled amphibians, the AArk aims to help partners identify conservation actions for species in need, put partners in possession of the necessary skills to manage those amphibians, provide guidelines for best management practices, and facilitate the formation of partnerships to sustain programs for their duration. AArk Conservation

Needs Assessment Workshops identify conservation actions for species in need (e.g., rescue, *in situ* conservation, *ex situ* research) on a country-by-country basis. Information on these workshops can be found online at http://www.amphibianark.org/conservation needs_workshops.htm. An AArk Taxon Officer works with the national/regional Chair of the IUCN/SSC Amphibian Specialist Group to assemble a similar team of experts to that which led the original 2004 Global Amphibian Assessment. The group then evaluates each species individually, answering a set of predetermined questions whose answers automatically assign species to conservation action lists. Results are posted on the AArk portal (http://www.amphibianark.org/assessment results.htm), thereby allowing conservation managers easy access to the information they need to make informed decisions and maximize the impact of their limited conservation resources. Since 2006, the conservation needs of 38% of the world's amphibian species have been evaluated in 23 workshops. This unique process has been embraced by other practitioners who have used it to evaluate Costa Rican trees (Cabezas et al. 2009) and in other planned workshops.

Once the needs of species are assessed and there is a clear directive on where to expend precious resources within a given range country, AArk works to encourage conservation action. AArk Training Workshops (http://www.amphibianark.org/husbandryworkshops.htm) provide technical information to partners carrying out hands-on work in caring for amphibians in captive programs. These workshops cover many topics, from basic husbandry and reproduction to nutrition and disease prevention, but also work to help personnel in range countries to develop, initiate, and maintain amphibian conservation programs. Since 2004, AArk staff and partners (notably the Association of Zoos and Aquariums and Durrell Wildlife Conservation Trust) have already trained > 1,600 students in amphibian biology, husbandry, and conservation practices through 51 courses in 29 countries.

There are a number of key management issues that the AArk and partners felt were important enough to warrant independent sets of guidelines and in some cases advisory groups. The AArk Population Management Advisory Group wrote the *AArk Amphibian Population Management Guidelines* (found at http://www.amphibianark.org/populationmanagement.htm) covering specific management techniques to maximize the maintenance of genetic diversity in captive populations. The AArk Biobanking Advisory Committee is working to assemble a 'handbook' of existing and emerging biobanking methodologies and an interactive web-database detailing existing repositories and the samples they contain. The AArk Biosecurity Advisory Group produced a best practices manual (Pessier and Mendelson 2010; available at: http://www.AmphibianArk.org/disease.htm). An AArk Re-introduction Advisory Group is planning production of *IUCN Re-introduction Specialist Group Guidelines for the Re-introduction of Amphibians*. Thanks to pioneering efforts of the Amphibian Research Centre in Australia, the AArk community has developed a practical and model response to emergency housing of imperiled amphibians through the modification of refrigerated cargo containers (found at: http://www.amphibianark.org/containers.htm). Last but not least, the AArk Research Officer has led production of an *AArk Amphibian Conservation Research Guide* (https://aark.portal.isis.org/ResearchGuide/ACRG/Amphibian%20Conservation%20Research%20Guide.pdf) to help partners identify projects that contribute to the goals of the ACAP. For more information, see AArk's Science and Research webpage at http://www.amphibianark.org/resources/science-and-research/.

Given the obvious disparity in the global distribution of threatened amphibians and resources to save them, the AArk has endeavored to further facilitate international partnerships to rescue species. The AArk partnership database at www.AArkFrogMatchMaker.com features rescue efforts in need of external support. This database currently includes 49 projects in 23 countries on four continents and can be searched by country, region, species, funding required, and by project type. Anyone who wants to have their project included in this database need only contact us. There are numerous model resource-sharing partnerships (Table 1).

Nearly 100 developing *ex situ* programs for priority rescue species are currently being tracked (http://portal.isis.org/partners/AARK/ExSituPrograms/default.aspx). While some of these programs meet all of the AArk's ideal attributes (e.g., sufficient founders, consistent breeding success, biosecurity, working in range country), most do not. There is much work to be done improving existing programs and initiating new programs for priority species not yet rescued.

Supporting other ACAP partners.—Because species can only be truly saved in the wild, and rescued organisms can only be released after threats are understood and mitigated, the AArk plan to successfully terminate programs is to support fellow ACAP partners who address those issues. To that end, some activities of the AArk community benefit all ACAP partners. The AArk's role in raising awareness has already been discussed; this work has created a more receptive environment in which all ACAP partners can fundraise. In addition, the *ex situ* community offers over two dozen grants that are not generally limited to *ex situ* activities and are therefore open to all ACAP partners (Grow and Poole 2007; see also http://ww.amphibianark.org/funding.htm). Furthermore,

TABLE 1. Model international partnerships wherein external funding partners share resources where they are most needed.

Range country partner	External partner(s)	Representative publication or website
Balsa de los Sapos, Ecuador	St. Louis Zoo	Zippel and Mendelson 2008
Cali Zoo, Colombia	Zoo Zurich	Furrer and Corredor 2008
Chapultepec Zoo, Mexico	Toronto Zoo	http://www.torontozoo.com/Conservation/habitat.asp?pg=habitat
Dominica and Montserrat governments	Durrell, London, Chester, and Parken Zoos	http://www.zsl.org/conservation/regions/americas/caribbean-amphibian-conservation/capacity-building-in-dominica,230,AR.html
El Valle Amphibian Conservation Center, Panama	Houston Zoo et al.	Gagliardo et al. 2008; http://www.houstonzoo.org/amphibians
Johannesburg Zoo, South Africa	Omaha Zoo	Van der Spuy and Krebs 2008
Summit Zoo, Panama	PARCP	http://www.amphibianrescue.org
Univ. de Concepción, Chile	Zoo Leipzig, Chester Zoo	http://www.zoo-leipzig.de/index.php?strg=19_41_74andbaseID=74
Univ. of Dar es Salaam	WCS, Toledo Zoo, World Bank	http://www.wcs.org/new-and-noteworthy/kihansi-toad-exhibit.aspx
Univ. of Hong Kong	Melbourne Zoo	Banks et al. 2008
Univ. Peruana Cayetano Heredia, Peru	Denver Zoo	http://www.denverzoo.org/conservation/project46.asp
Institute of Ecology and Biological Resources, Vietnam	Cologne Zoo	Ziegler 2010
Zoo Amaru, Ecuador	Philadelphia Zoo	http://www.philadelphiazoo.org/phila/Conservation---Travel/Protecting-Wildlife/Andean-Amphibians.htm
Zoológico Nacional, Chile	Atlanta Botanical Garden	http://www.savedarwinsfrogs.org

if the ACAP is being executed properly and collaborative partnerships are formed across multiple disciplines and communities, then each can count each other's resources as in-kind support to leverage additional funds. The AArk has also been able to help field partners raise funds (approx. USD $25,000 to date for Venezuela) by selling the naming rights of new species (e.g., *Mannophryne speeri*, La Marca 2009; *Anomaloglossus verbeeksnyderorum*, Barrio-Amorós et al. 2010).

In addition to conducting important research on ACAP priorities, the AArk community can help other ACAP partners by making available animals that are surplus to managed rescue populations (see http://www.amphibianark.org/mailman/listinfo/animalsforacap_amphibianark.org). While many *ex situ* partners have disposition policies that cannot support this activity, many do not, and new collaborations have resulted in important studies, such as toxicology work (Daly et al. 1997; Chen et al. 2005, 2006; Wang et al. 2008), and disease research (Bustamante et al. 2010; Berger et al. 2005).

Furthermore, while assessing the status of species in the wild is not in itself a priority for *ex situ* partners, many comprehensive rescue programs are supporting *in situ* specialists or conducting surveys themselves, generating data that are useful in conservation assessments, including discovery and description of new species (Ziegler 2010). Often these assessment efforts aim to determine the distribution of populations within a target species and partners simultaneously conduct phylogenetic analyses to determine which populations are distinct and require independent management (e.g., Mallorcan Midwife Toad, Kraaijeveld-Smit et al. 2005; Central American harlequin frogs (*Atelopus* spp.), Zippel et al. 2007; Green and Golden Bell Frog (*Litoria aurea*), Daly et al. 2008; Australian corroboree frogs (*Pseudophryne* spp.), Morgan et al. 2008; Natterjack Toad (*Epidalea calamita*), Allentoft et al. 2009; Puerto Rican Crested Toad, Beauclerc et al. 2010).

Finally, although identification and protection of key habitat areas is not a focal area of the *ex situ* community, these *in situ* and *ex situ* efforts can and must complement each other. For example, when *in situ* ACAP partners secure key habitat areas for a particular amphibian species, AArk partners should focus on assessing and addressing the *ex situ* needs of those species. Protecting the habitat of a species is futile if that species is going to succumb to threats that ignore park borders. For example, while the Alliance for Zero Extinction and partners purchased and protected key habitat in Sierra Nevada de Santa Marta Colombia (http://ww.amphibians.org/ASG/Colombia.html), the Barranquilla Zoo began looking for support to initiate a rescue program for *Colostethus ruthveni* (see http://www.amphibianark.org/Colostethus_ruthveni.htm), a species predicted to be negatively impacted by *Bd* (Rödder et al. 2009). The reverse also applies: if *ex situ* partners have been able to rescue a particular species that does not occur in a protected area, collaboration should occur with *in situ* partners to protect habitat. Rescuing a species with no potential for release into protected habitat is as futile for the amphibian species in question as protecting habitat for species facing unmitigable threats. This sort of complementary collaboration should be a priority for *ex situ* partners and is another channel for their resources to benefit their *in situ* partners.

Likewise, the scientific community can help the AArk. In addition to focusing on research questions that further the ACAP agenda, there is no reason scientific institutions cannot maintain rescue populations for their research (Zippel and Mendelson 2008). Throughout the global scientific community, there are countless colonies of inbred Least Concern African Clawed Frogs (*Xenopus laevis*), as well as Axolotls (*Ambystoma mexicanum*) that, although Critically Endangered as a species, are also inbred as laboratory specimens. Could not the same research questions be answered using animals in need of rescue? Instead of albino Axolotls, study wild-type Axolotls of known and valuable genetic descent, or any of a number of other Critically Endangered Mexican obligate larviform ambystomatids. Instead of albino Clawed Frogs, study Endangered *Xenopus gilli* or Critically Endangered *X. longipes*, or any of the other approx. 2,000 threatened amphibian species, simultaneously providing research subjects and an assurance population against extinction. To our knowledge, there are only a few universities or museums that maintain amphibians for (among other reasons) assurance populations against extinction (see Zippel and Mendelson 2008).

Summary.—The amphibian extinction crisis is perhaps the greatest taxon-specific conservation challenge in the history of humanity. While most threatened amphibian species can, and should, be saved in the wild, many are facing threats that cannot or will not be mitigated in time to prevent their extinction. The Amphibian Ark is an umbrella organization uniting *ex situ* partners around the world, improving their efforts to rescue those species in need and promoting collaborations to mitigate threats and secure species in the wild.

Acknowledgments.—Our deepest gratitude goes out to those institutions who have donated: staff time or salary to fill the roles of the AArk Officers (Chester Zoo, Chicago Zoological Society, Philadelphia Zoo, Zoo Atlanta, Zoological Society of Antwerp, Zoological Society of London) and Executive and Steering Committees (see http://www.amphibianark.org/about-us/aark-organization/), office space to house AArk Officers (Chester Zoo, Philadelphia Zoo, Woodland Park Zoo, Australasian Zoo and Aquarium Association , Zoo Atlanta, Zoological Society of Antwerp, Zoological Society of London), funds for general operating support (see www.amphibianark.org/acknowledgements.htm) in particular the European Association of Zoos and Aquariums. We also wish to thank our primary corporate sponsor, The Clorox Company. Special thanks to Richard Griffiths, Franco Andreone, and Ariadne Angulo for helpful comments.

LITERATURE CITED

Allentoft, M.E., and J. O'Brien. 2010. Global amphibian declines, loss of genetic diversity and fitness: A review. Diversity 2:47–71.

Allentoft, M.E., H.R. Siegismund, L. Briggs, and L.W. Andersen. 2009. Microsatellite analysis of the Natterjack Toad (*Bufo calamita*) in Denmark: populations are islands in a fragmented landscape. Conservation Genetics 10:15–28.

Banks, C.B., M.W.N. Lau, and D. Dudgeon. 2008. Captive management and breeding of Romer's Tree Frog *Chirixalus romeri*. International Zoo Yearbook 42:99–108.

Barrio-Amorós, C.L., J.C. Santos, and O. Jovanovic. 2010. A new dendrobatid frog (Anura: Dendrobatidae: *Anomaloglossus*) from the Orinoquian rainforest, southern Venezuela. Zootaxa 2413:37–50.

Beauclerc, K.B., B. Johnson, and B.N. White. 2010. Genetic rescue of an inbred captive population of the critically endangered Puerto Rican Crested Toad (*Peltophryne lemur*) by mixing lineages. Conservation Genetics 11:21–32.

Beck, B.B., L.G. Rappaport, M.R. Stanley-Price, and A.C. Wilson. 1994. Reintroduction of captive-born animals. Pp. 265–284 *In* Creative Conservation. Olney, P.J.S., G.M. Mace, and A.T.C. Feistner (Eds.). Chapman and Hall, London, UK.

Berger, L., G. Marantelli, L.F. Skerratt, and R. Speare. 2005. Virulence of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* varies with the strain. Diseases of Aquatic Organisms 68:47–50.

Berger, L., R. Speare, P. Daszak, D. Green, A. Cunningham, C. Goggin, R. Slocombe, M. Ragan, A. Hyatt, K. McDonald, H. Hines, K. Lips, G. Marantelli, and H. Parkes. 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 95:9031–9036.

Bielby, J., N. Cooper, A.A. Cunningham, T.W.J. Garner, and A. Purvis. 2008. Predicting susceptibility to future declines in the world's frogs. Conservation Letters 1:82–90.

Buley, K.R., and G. Garcia. 1997. The recovery programme for the Mallorcan Midwife Toad *Alytes muletensis*: An update. Dodo: Journal of the Jersey Wildlife Preservation Trusts 33:80–90.

Bustamante, H.M., L.J. Livo, and C. Carey. 2010. Effects of temperature and hydric environment on survival of the Panamanian Golden Frog infected with a pathogenic chytrid fungus. Integrative Zoology 5:143–153.

Cabezas, F., J.E. Rodriguez, and Y. Matamoros. 2009. Proceso de Priorización e Implementación para la Conservación *ex situ* de Especies Arbóreas Nativas de los Cantones de Santa Ana, Escazú, Mora, y Belén, Costa Rica. Conservation Breeding Specialist Group, Santa Ana, Costa Rica.

Chen, T., R. Gagliardo, B. Walker, M. Zhou, and C. Shaw. 2005. Partial structure of the phylloxin gene from the Giant Monkey Frog, *Phyllomedusa bicolor*: Parallel cloning of precursor cDNA and genomic DNA from lyophilized skin secretion. Peptides 26:2624–2628.

Chen, T., M. Zhou, R. Gagliardo, B. Walker, and C. Shaw. 2006. Elements of the granular gland peptidome and transcriptome persist in air-dried skin of the South American Orange-legged Leaf Frog, *Phyllomedusa hypochondrialis*. Peptides 26:2129–2136.

Daly, G., P. Johnson, G. Malolakis, A. Hyatt, and R. Pietsch. 2008. Reintroduction of the Green and Golden Bell Frog *Litoria aurea* to Pambula on the south coast of New South Wales. Australian Zoologist 34:261–270.

Daly, J.W., W.L. Padgett, R.L. Saunders, and J.F. Cover Jr. 1997. Absence of tetrodotoxins in a captive-raised riparian frog, *Atelopus varius.* Toxicon 35:705–709.

Farrer, R.A., L.A. Weinert, J. Bielby, T.W.J. Garner, F. Balloux, F. Clare, J. Bosch, A.A. Cunningham, C. Weldon, L.H. du Preez, L. Anderson, S.L. Kosakovsky Pond, R. Shahar-Golan, D.A. Henk, and M.C. Fisher. 2011. Multiple emergences of genetically diverse amphibian-infecting chytrids include a globalized hypervirulent recombinant lineage. Proceedings of the National Academy of Sciences 108:18732–18736.

Fisher, M.C., and T.W.J. Garner. 2007. The relationship between the emergence of *Batrachochytrium dendrobatidis*, the international trade in amphibians and introduced amphibian species. Fungal Biology Reviews 21:2–9.

Fisher, M.C., T.W.J. Garner, and S.F. Walker. 2009 Global emergence of *Batrachochytrium dendrobatidis* and amphibian chytridiomycosis in space, time, and host. Annual Review of Microbiology 63:291–310.

Furrer, S.C., and G. Corredor. 2008. Conservation of threatened amphibians in Valle del Cauca, Colombia: a cooperative project between Cali Zoological Foundation, Colombia, and Zoo Zürich, Switzerland. International Zoo Yearbook 42:158–164.

Gagliardo, R., P. Crump, E. Griffith, J. Mendelson, H. Ross, and K. Zippel. 2008. The principles of rapid response for amphibian conservation, using the programmes in Panama as an example. International Zoo Yearbook 42:125–135.

Garner, T.W.J., M. Perkins, P. Govindarajulu, D. Seglie, S.J. Walker, A.A. Cunningham, and M.C. Fisher. 2006. The emerging amphibian pathogen *Batrachochytrium dendrobatidis* globally infects introduced populations of the North American Bullfrog, *Rana catesbeiana*. Biology Letters 2:455–459.

Gascon, C., J.P. Collins, R.D. Moore, D.R. Church, J.E. McKay, and J.R. Mendelson III (Eds.). 2007. Amphibian Conservation Action Plan. IUCN/SSC Amphibian Specialist Group, Gland, Switzerland.

Germano, J.M., and P.J. Bishop. 2008. Suitability of amphibians and reptiles for translocation. Conservation Biology 23:7–15.

Goka, K., J. Yokoyama, Y. Une, T. Kuroki, K. Suzuki, M. Nakahara, A. Kobayashi, S. Inaba, T. Mizutani, and A.D. Hyatt. 2009. Amphibian chytridiomycosis in Japan: distribution, haplotypes and possible route of entry into Japan. Molecular Ecology 18:4757–4774.

Griffiths, R.A., and L. Pavajeau. 2008. Captive breeding, reintroduction, and the conservation of amphibians. Conservation Biology 22:852–861.

Grow, S., and V.A. Poole. 2007. AZA Amphibian Conservation Resource Manual. Appendix 3. Association of Zoos and Aquariums, Silver Spring, Maryland, USA.

Gusset, M., and G. Dick. 2010. The global reach of zoos and aquariums in visitor numbers and conservation expenditures. Zoo Biology 29:1–4.

Harris, R.N., A. Lauer, M.A. Simon, J.L. Banning, and R.A. Alford. 2009. Addition of antifungal skin bacteria to salamanders ameliorates the effects of chytridiomycosis. Diseases of Aquatic Organisms 83:11–16.

IUCN. 2002. IUCN Technical Guidelines on the Management of *Ex-situ* Populations for Conservation. International Union for Conservation of Nature, Gland, Switzerland.

IUCN, Conservation International, and NatureServe. 2011. Red List of Threatened Species. Available from http://www.iucnredlist.org [Accessed 5 May 2011].

Johnson, B. 1999. Recovery of the Puerto Rican Crested Toad. Endangered Species Bulletin 24:8–9.

Kraaijeveld-Smit, F.J.L., T.J.C. Beebee, R.A. Griffiths, R.D. Moore, and L. Schley. 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., R.A. Griffiths, R.D. Moore, and T.J.C. Beebee. 2006. Captive breeding and the fitness of reintroduced species: a test of the responses to predators in a threatened amphibian. Journal of Applied Ecology 43:360–365.

Krajick, K. 2006. The lost world of the Kihansi Spray Toad. Science 311:1230–1232.

La Marca, E. 2009. A frog survivor (Amphibia: Anura: Aromobatidae: *Mannophryne*) of the traditional coffee belt in the Venezuelan Andes. Herpetotropicos 5:49–54.

Longcore, J.E., A.P. Pessier, and D.K. Nichols. 1998. Morphology and zoospore ultrastructure of a chytrid pathogenic to anuran amphibians. Inoculum (Supplement to Mycologia) 49:33.

Longcore, J.E., A.P. Pessier, and D.K. Nichols. 1999. *Batrachochytrium dendrobatidis* gen. et. sp. nov., a chytrid pathogenic to amphibians. Mycologia 91:219–227.

McCallum, M.L. 2007. Amphibian decline or extinction? Current declines dwarf background extinction rate. Journal of Herpetology 41:483–491.

Mendelson III, J.R., K.R. Lips, R.W. Gagliardo, G.B. Rabb, J.P. Collins, J.E. Diffendorfer, P. Daszak, R. Ibanez D., K.C. Zippel, D.P. Lawson, et al. 2006. Confronting amphibian declines and extinctions. Science 313:48.

Moore, R.D., R.A. Griffiths, and A. Roman. 2004. Distribution of the Mallorcan Midwife Toad (*Alytes muletensis*) in relation to landscape topography and introduced predators. Biological Conservation 116:327–332.

Morgan, M.J., D. Hunter, R. Pietsch, W. Osborne, and J.S. Keough. 2008. Assessment of genetic diversity in the critically endangered Australian Corroboree Frogs, *Pseudophryne corroboree* and *Pseudophryne pengilleyi*, identifies four evolutionary significant units for conservation. Molecular Ecology 17:3448–3463.

Murphy, J.B. 2007. Herpetological History of the Zoo and Aquarium World. Krieger Publishing Company, Malabar, Florida, USA.

Nichols, D.K., and E.W. Lamirande. 2000. Treatment of cutaneous chytridiomycosis in Blue-and-yellow Poison Dart Frogs (*Dendrobates tinctorius*). Pp. 51 *In* Proceedings: Getting the Jump on Amphibian Disease. Speare, R. (Ed.). James Cook University, Cairns, Australia.

Parra, G., R. Brown, J. Hanken, B. Hedges, R. Heyer, S. Kuzmin, E. Lavilla, S. Lötters, B. Pimenta, S. Richards, M.O. Rodel, R.O. De Sa, and D. Wake. 2007. Systematics and conservation. Pp. 45–48 *In* Amphibian Conservation Action Plan. Gascon, C., J.P. Collins, R.D. Moore, D.R. Church, J.E. McKay, and J.R. Mendelson III (Eds.). IUCN/SSC Amphibian Specialist Group, Gland, Switzerland.

Pavajeau, L., K.C. Zippel, R. Gibson, and K. Johnson. 2008. Amphibian Ark and the 2008 Year of the Frog campaign. International Zoo Yearbook 42:24–29.

Pessier, A.P., and J.R. Mendelson (Eds.). 2010. A Manual for Control of Infectious Diseases in Amphibian Survival Assurance Colonies and Reintroduction Programs. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Raxworthy, C.J., R.G. Pearson, N. Rabibisoa, A.M. Rakotondrazafy, J.B. Ramanamanjato, A.P. Raselimanana, S. Wu, R.A. Nussbaum, and D.A. Stone. 2008. Extinction vulnerability of tropical montane endemism from warming and upslope displacement: a preliminary appraisal for the highest massif in Madagascar. Global Change Biology 14:1703–1720.

Richmond, J.Q., A.E. Savage, K.R. Zamudio, and E.B. Rosenblum. 2009. Toward immunogenetic studies of amphibian chytridiomycosis: linking innate and acquired immunity. Bioscience 59:311–320.

Robertson, H., P. Eden, G. Gaikhorst, P. Matson, T. Slattery, and S. Vitali. 2008. An automatic waste-water disinfection system for an amphibian captive-breeding and research facility. International Zoo Yearbook 42:53–57.

Rödder, D., J. Kielgast, J. Bielby, S. Schmidtlein, J. Bosch, T.W.J. Garner, M. Veith, S. Walker, M.C. Fisher, and S. Lötters. 2009. Global amphibian extinction risk assessment for the panzootic chytrid fungus. Diversity 1:52–66.

Roelants, K., D.J. Gower, M. Wilkinson, S.P. Loader, S.D. Biju, K. Guillaume, L. Moriau, and F. Bossuyt. 2007. Global patterns of diversification in the history of modern amphibians. Proceedings of the National Academy of Sciences 104:887–892.

Rovito, S.M., G. Parra-Olea, C.R. Vásquez-Almazán, T.J. Papenfuss, and D.B. Wake. 2009. Dramatic declines in neotropical salamander populations are an important part of the global amphibian crisis. Proceedings of the National Academy of Sciences 106:3231–3236.

Secretariat of the Convention on Biological Diversity. 2001. Handbook on the Convention on Biological Diversity. Earthscan Publications, Ltd., London, England.

Skerratt, L.F., L. Berger, R. Speare, S. Cashins, K.R. Mcdonald, A. Phillott, H. Hines, and N. Kenyon. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. EcoHealth 4:125–134.

Snyder, N.F., S.R. Derrickson, S.R. Beissinger, J.W. Wiley, T.B. Smith, W.D. Toone, and B. Miller. 1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10:338–348.

Stice, M.J., and C.J. Briggs. 2010. Immunization is ineffective at preventing infection and mortality due to the amphibian chytrid fungus *Batrachochytrium dendrobatidis*. Journal of Wildlife Diseases 46:70–77.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinction worldwide. Science 306:1783–1786.

Stuart, B.L., A.G.J. Rhodin, L.L. Grismer, and T. Hansel. 2006. Scientific description can imperil species. Science 312:1137.

Van Der Spuy, S.D., and J. Krebs. 2008. Collaboration for amphibian conservation: the establishment of the Johannesburg Zoo Amphibian Conservation Center in South Africa with assistance from Omaha's Henry Doorly Zoo, USA. International Zoo Yearbook 42:165–171.

Waldman, B., and J.S. McKinnon. 1993. Inbreeding and outbreeding in fishes, amphibians, and reptiles. Pp. 250–282 *In* The Natural History of Inbreeding and Outbreeding: Theoretical and Empirical Perspectives. Thornhill, N.W. (Ed.). University of Chicago Press, Chicago, Illinois, USA.

Walker, S.F., J. Bosch, T.Y. James, A.P. Litvintseva, J.A.O. Valls, S. Piña, G. García, G.A. Rosa, A.A. Cunningham, S. Hole, R. Griffiths, and M.C. Fisher. 2008. Invasive pathogens threaten species recovery programs. Current Biology 18:R853–854.

Wang, L., M. Zhou, A. McClelland, A. Reilly, T. Chen, R. Gagliardo, B. Walker, and C. Shaw. 2008. Novel dermaseptin, adenoregulin, and caerin homologs from the Central American Red-eyed Leaf Frog, *Agalychnis callidryas*, revealed by functional peptidomics of defensive skin secretion. Biochime 90:1435–1441.

WAZA. 2005. Building a Future for Wildlife - The World Zoo and Aquarium Conservation Strategy. WAZA, Bern, Switzerland.

Weldon, C., L.H. Du Preez, A.D. Hyatt, R. Muller, and R. Speare. 2004. Origin of the amphibian chytrid fungus. Emerging Infectious Diseases 10:2100–2105.

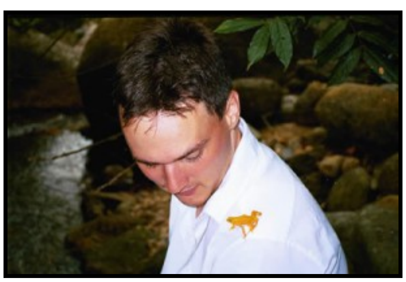
Ziegler, T. 2010. Amphibian and reptilian diversity research, conservation and breeding projects in Vietnam. Pp. 117–122 *In* Building a Future for Wildlife: Zoos and Aquariums Committed to Biodiversity Conservation. Dick, G., and M. Gusset (Eds.). WAZA Executive Office, Gland, Switzerland.

Zippel, K., K. Buley, R. Gibson, G.R. Gillespie, R. Johnson, R.C. Lacy, G. Marantelli, and J.R. Mendelson III. 2008. On the role of *ex situ* management in the conservation of amphibians. Pp. 128–129 *In* Threatened Amphibians of the World. Stuart, S.N., M. Hoffman, J.S. Chanson, N.A. Cox, R.J. Berridge, P. Ramani, and B.E. Young (Eds.). Lynx Edicions, Barcelona, Spain.

Zippel, K.C., R.D. Ibáñez, E.D. Lindquist, C.L. Richards, C.A. Jaramillo, and E.J. Griffith. 2007. Implicaciones en la conservación de las ranas doradas de Panamá, asociadas con su revisión taxonómica. Herpetotropicos 3:29–39.

Zippel, K., R. Lacy, and O. Byers. (Eds.). 2006. CBSG/WAZA Amphibian *Ex Situ* Conservation Planning Workshop Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Zippel, K.C., and J.R. Mendelson III. 2008. The amphibian extinction crisis: a call to action. Herpetological Review 39:23–29.



Kevin Zippel received his B.S. in 1994 from Cornell University and his Ph.D. in 2000 from the University of Florida. He spent one year (1999) as a curatorial intern in the Department of Herpetology at the Wildlife Conservation Society/Bronx Zoo while he finished his doctorate. Kevin then went on to work five years as Curator of Amphibians at the Detroit Zoo. During his years in Detroit, he became an Adjunct Associate Professor at Michigan State University and George Mason University. In 2005, Kevin joined the IUCN's Conservation Breeding Specialist Group to help the zoo community develop and implement plans to stem the amphibian extinction crisis. These efforts evolved into the Amphibian Ark, which Kevin serves as Program Director. (Photographed by Corinne L. Richards Zawacki).

Kevin Johnson has worked in the zoo community since the early 1980s. He started as a keeper in the Veterinary Department of the Melbourne Zoo. Since that time he lead the computerization of the zoo's animal records system, developed additional reports for the ARKS software, developed by ISIS, and helped with development of the computerized animal collection planning software, REGASP. Kevin worked at the Zoo and Aquarium Association (ZAA, formerly ARAZPA) office in Sydney, Australia from 1993-2010. He was on full-time appointment to the Amphibian Ark since 2007. Kevin provided training and user support for the animal records programs distributed by the International Species Information System (ISIS) to users throughout the region. He was Chair of the International Animal Data Information Systems Committee and was Chair of ZAA's Animal Records Keeping Specialist Group for a number of years. Kevin worked in the development of the next generation of ISIS software, ZIMS (the Zoological Information Management System) during the first five years of this project. He now works full-time for the AArk as Taxon Officer and Communications/Development Officer, and is based on the mid-north coast of New South Wales, Australia. (Photographed by Richard Gibson).

RON GAGLIARDO spent his early years growing up near the Everglades National Park in south Florida, USA, where he developed what has become a lifelong passion and interest in herpetology. Although he was trained as a chemist and received his undergraduate and graduate degrees in Botany from North Carolina State University in 1987 and 1992, he has maintained a deep interest in amphibians and reptiles. In 1993, Ron joined the Atlanta Botanical Garden where he worked until 2008 developing the Garden's tropical plant collections as Curator and also Manager of the Garden's Plant Tissue Culture Laboratory. In 2001, Ron began to put the techniques of captive breeding to use in the conservation field and developed an active amphibian conservation program. This program included components of fundraising, education, captive breeding research and support of range country partners in Costa Rica, Panama, Ecuador, and Peru. Ron facilitates *ex situ* programs as the AArk's Training Officer. (Photographed by Paul Huggett)

RICHARD GIBSON graduated from the University of Nottingham in 1992. He then worked for the Durrell Wildlife Conservation Trust (DWCT) for almost 10 years as Head of Herpetology. After leaving DWCT in 2001, he spent 18months running bird and reptile field projects in Mauritius, before taking up the position of Curator of Herpetology at the Zoological Society of London (ZSL). During his time at ZSL, he began to work part-time for AARK. In 2008 Richard moved to Chester Zoo where he served as Curator of Lower Vertebrates & Invertebrates until mid 2011. Richard is currently affiliated with the Auckland Zoo where he continues to work part-time as an AArk Taxon Officer. (Photographed by Claudio Ciofi)

MICHAEL MCFADDEN received his B.Sc. Hons. in Environmental Biology from the University of Technology, Sydney,Australia, in 2002. He went straight on to work as a keeper in the Herpetofauna Department at Taronga Zoo in Sydney, Australia, before becoming the unit supervisor of the department in 2005. Michael is also currently the co-convenor of the Amphibian Taxon Advisory Group for Australia's Zoo and Aquarium Association. His current work focuses on the ex-situ conservation of threatened amphibian species in southeast Australia. This includes co-coordinating programs for Corroboree frogs (*Pseudophryne* spp.), the Booroolong Frog (*Litoria booroolongensis*), and the recently rediscovered Yellow-spotted Bell Frog (*Litoria castanea*). This work mostly involves establishing breeding techniques and investigating reintroduction protocols. In recent years, Michael has also assisted AArk in delivering a number of husbandry workshops in the Australasian region.. (Photographed by Dean Purcell)

ROBERT BROWNE graduated with a Ph.D. in Reproduction Technologies for Amphibians from the University of Newcastle, Australia, in 1998, and previously worked as Amphibian Ark's Research Officer half-time during 2008. Robert has experience in a wide range of research fields directed toward amphibian conservation. He has researched and published in fields including amphibian nutrition, pathology, tadpole growth and development, tadpole husbandry, the thermobiology of frogs, amphibian reproduction technologies, amphibian care, and facility design. Robert's work in the late 1990s was seminal to the development of both *ex situ* techniques for the reproduction of amphibians and for gene banking to preserve genetic diversity of declining populations. Progress in reproduction technologies since then has lead to the first use of in vitro techniques for the production of tadpoles of an endangered species for release, and the cryopreservation of sperm of cell lines in the African Clawed Toads (*Xenopus* spp.) for medical research. (Photographed by Jasmine Stewert)

CARLOS MARTINEZ is from the island of Puerto Rico and he completed his B.Sc. in biology with a minor in botany at the University of Puerto Rico-Mayagüez in 2001. As an undergraduate student, he helped in projects working with various Coqui frogs, the Puerto Rican boa (*Epicrates inornatus*), and in a head-starting program for the Puerto Rico population of the Cuban rock iguana (*Cyclura nubila*). Carlos then moved to the US to pursue his doctoral studies at the University of Missouri-Columbia, which he finished in 2008. His doctoral dissertation consisted of trying to understand how sexual selection shapes the evolution of frog calling behavior and male-male interactions in noisy, competitive environments (frog choruses), and how females select individual mates from the chaos of the chorus. For his dissertation, Carlos focused his work on the bird-voiced (*Hyla avivoca*) and canyon (*H. arenicolor*) treefrogs. In July 2008, Carlos joined the Philadelphia Zoo as Curator of Amphibians and Reptiles and Amphibian Conservation Biologist, and served the AArk part-time as a liaison to Latin American programs. (Photographed by Ruth Percino Daniel)

ELIZABETH TOWNSEND works as an administrative assistant for the IUCN/SSC Conservation Breeding Specialist Group (CBSG) and, as part of CBSG's commitment to support the efforts of AArk, she spends part of her time working for AArk, primarily dealing with financials. Elizabeth graduated from the University of Wisconsin-Madison in 2000 with a B.A. in Zoology and French. (Photographed by Molly Townsend)