Amphibian Population Declines in Latin America: A Synthesis

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ABSTRACT

The loss of global amphibian biodiversity has been well documented in recent years. The greatest information from Latin America came from countries such as Costa Rica, Panama, Ecuador, and Puerto Rico. The five papers in this special section illustrate the critical status of Latin American amphibians and further demonstrate certain commonalities of amphibian population declines within the region. These studies provide a framework by which future research and management could proceed in all tropical regions.

RESUMEN

En los pasados años se ha documentado la pérdida de biodiversidad de anfibios en muchas partes del mundo. La mayor información con respecto a América Latina proviene de trabajos realizados en Costa Rica, Panamá, Ecuador y Puerto Rico. Los cinco trabajos de esta edición especial ilustran el estado crítico de los anfibios en América Latina y demuestran que existen algunos elementos comunes en los patrones de disminuciones poblacionales de anfibios en la región. Estos estudios proveen un marco de referencia para futuras investigaciones y desarrollo de planes de manejo en regiones tropicales.

Key words: anurans; Batrachochytrium dendrobatidis; Brazil; salamanders; deforestation; Ecuador; Mexico; montane regions.

AMONG THE MOST STRIKING REPORTS OF AMPHIBIAN DECLINES IN LATIN AMERICA is the story of Costa Rica, a country acknowledged as a center for ecotourism. In the early 1990s, scientists documented the loss of the golden toad (Bufo periglenes) and the harlequin frog (Atelopus varius) from the mountains of the Monteverde Cloud Forest Reserve (Crump et al. 1992, Pounds & Crump 1994). The news attracted the attention of many herpetologists working in Central and South America. Since then, severe amphibian declines in Costa Rica and mass mortalities in Panama have been associated with the presence of Batrachochytrium dendrobatidis, a pathogenic fungus (Lips 1998, 1999). Biologists working in other areas of Latin America also reported declines, extinctions, or changes in frog communities in southeastern Brazil (Heyer et al. 1988, Weygoldt 1989), Venezuela (La Marca & Reinthaler 1991), Puerto Rico (Stewart 1995, Joglar & Burrowes 1996), and Ecuador (Ron et al. 2001–2004). These efforts led to calls for long-term monitoring, attention to patterns and trends, and testing of particular hypotheses regarding potential causes of declines throughout the region. After the turn of the millennium, new research summarized the conservation status of amphibians in Latin America (Young et al. 2001, Stuart et al. 2004), contributed insights on ecological patterns of declining amphibians (Lips et al. 2003, Ranvestal et al. 2004, Lips & Donnelly 2005), and provided evidence of potential causes of decline (Merino-Viteri 2001, Puschendorf 2003, Burrowes et al. 2004, Lips et al. 2004).

Based on these and other contributions, some factors can now be reliably associated with amphibian declines in Latin America and across the globe. Species that inhabit moderate to high elevations, have aquatic larvae, and a relatively high degree of ecological specialization are generally at risk. While habitat alteration and deforestation can be directly linked to some declines, numerous extirpations of populations from remote or protected areas around the world have been associated with recently discovered (and recently emerged) pathogens such as Batrachochytrium dendrobatidis. Complex synergistic interactions among climate change, disease, and contamination have been posited, but experimental data are lacking for any tropical country. Here, we summarize what is known about amphibian population declines in Latin America, highlight new findings presented in the five contributed papers in this special section, and suggest future directions for research and management.
THE GEOGRAPHIC AND TAXONOMIC EXTENT OF THE PROBLEM

Many reports of amphibian declines have come from repeated visits to a particular site rather than a broad-scale survey of a region or country or from a search for a particular species or other taxonomic group. Although most regions in Latin America have never been surveyed, the collective experience of Research and Analysis Network for Neotropical Amphibians (RANA) members suggests that intact amphibian communities no longer exist throughout most upland (>500 m) areas of the Neotropics. Based on surveys of experts (La Marca et al. 2005), published reports (Eterovick et al. 2005), and historic collecting sites (Bustamante et al. 2005), the papers in this special section provide a striking example of the broad geographic extent (~840,000 km²) of amphibian declines, and the large number of taxa affected (107 species, 24 genera, and 5 families). While many amphibian declines occurred in Latin America during the 1980s (Young et al. 2001), the phenomenon is ongoing.

One of the broadest surveys of species and localities was that carried out by researchers at the Museo de Zoológica, Universidad Católica del Ecuador (Bustamante et al. 2005). These surveys covered seven sites in the Andes of northern Ecuador, and resurveyed 88 populations of 73 species. Initial population data were obtained by field parties from the Natural History Museum of the University of Kansas between 1960 and 1970, and by parties from Universidad Católica in the 1980s. Reports revealed that in 19 sites, 44 species and 56 populations of Ecuadorian amphibians have declined in the last 20–40 yr (Ron et al. 2003, Bustamante et al. this volume, Merino-Viteri et al. in press, Ron et al. in press), almost doubling previous estimates of 24 species (Ron et al. 2001–2004). In the case of Atelopus species, La Marca et al. (2005) report that at least 42 (37%) of the 113 existing or proposed species have declined and only ten (9%) species might be considered “stable.” This finding is significant because previous estimates for the genus were limited to five species at well-studied sites. Based on a literature survey of research in the Atlantic Coastal Forest of Brazil (Eterovick et al. 2005), at least 30 species have declined, including losses from Ceará and Paraná, two regions not previously identified. All five contributed papers emphasize that conclusions are based on relatively few species or areas, and that greater efforts will undoubtedly increase the number of species known to be at risk.

FACTORS THAT CONTRIBUTE TO AMPHIBIAN POPULATION DECLINE

Stuart et al. (2004) found three factors contributed most to amphibian population declines, habitat loss, overexploitation, and enigmatic declines (probably disease and climate change). At least four species of Brazilian anurans have declined as a result of habitat alteration (Eterovick et al. 2005), and two species of Atelopus have disappeared following deforestation (La Marca et al. 2005). Further, habitat loss might be contributing to elevational range shifts in Ecuadorian (Bustamante et al. 2005) and Mexican species (Parra-Olea et al. 2005).

Disease is strongly associated with Neotropical amphibian population declines. A virulent fungal pathogen of amphibians, Batrachochytrium dendrobatidis, has been found at several sites where species have suffered population declines (Berger et al. 1998, Lips 1999, Ron et al. 2003, Burrowes et al. 2004). This organism kills adult frogs probably through disrupting homeostasis and is considered an emerging infectious disease of amphibians (Daszak et al. 1999). In the lab, Batrachochytrium dendrobatidis grows best under cool, humid conditions (Piotrowski et al. 2004), which might explain its greater impact on montane amphibian populations (Stuart et al. 2004). Batrachochytrium dendrobatidis has been detected in 14 species of Atelopus (nine of which have disappeared) and it has been found in at least seven species of montane frogs from Ecuador (Ron & Merino-Viteri 2000), ten in Costa Rica (Puschendorf 2003, Lips et al. 2003), ten in Panama (Lips 1999), five in Venezuela (La Marca, pers. comm., Bonaccorso et al. 2003), three in Puerto Rico (Burrowes et al. 2004), and at least three in Mexico (Rollins-Smith et al. 2002, Lips et al. 2004). Given patterns predicted by Ron (2005), B. dendrobatidis is likely to threaten amphibians in 12 Neotropical areas, including many species in unexplored biodiversity hotspots of Mexico (Parra-Olea et al. 2005), Central America (e.g., Nicaragua), South America (e.g., Colombia, Bolivia, Brazil, Peru), and the Caribbean (e.g., Cuba, Hispaniola).

Climate change has been implicated in declines of some Neotropical amphibians (Pounds et al. 1999, Ron et al. 2003, Burrowes et al. 2004). Bustamante et al. (2005) documented upward shifts of nine Ecuadorian species in the last 20+ years. Environmental temperature and moisture patterns can influence amphibian ecology, physiology, and behavior because amphibians must maintain moist skin for oxygen and ionic exchange. As a result, scientists have focused on the effects of environmental factors in population declines (Pounds et al. 1999, Alexander & Eisechid 2001, Carey et al. 2001, Stallard 2001); and while direct links between individual mortality, population declines, and climate change are lacking, interactions between climate change and other agents are likely (Carey & Alexander 2003). Even broadly distributed amphibians may be threatened by climate change; ecological-niche modeling predicts severe habitat reduction and associated changes in climate for upland Mexican amphibians in the next 50 yr (Parra-Olea et al. 2005).

Survival and growth of B. dendrobatidis are influenced by temperature and moisture (Piotrowski et al. 2004), so climate change will influence the distribution, dispersal, and persistence of this pathogen. Ron’s (2005) model predicted the distribution of this pathogen under current environmental conditions and it will be important to model future changes under scenarios of climate change.

PATTERNS OF AMPHIBIAN POPULATION DECLINES VARY AMONG SPECIES

The tremendous species richness of the Neotropics allows comparison of species’ responses at a site (e.g., Lips et al. 2003). For example, Bustamante et al. (2005) reported that only one species of Eleutherodactylus, a group of mostly direct-developing terrestrial frogs, experienced population declines at seven sites in Ecuador. In contrast, many sympatric semiaquatic species representing other genera and families showed great declines, suggestive of an interaction between habitat and amphibian ecology. Phylogenetic effects related to declines (Stuart et al. 2004) or susceptibility to pathogens (Daszak et al. 2004) are also likely. Unfortunately, the lack of a robust phylogeny of anuran species limits testing for such
WHAT CAN WE DO TO MITIGATE AMPHIBIAN DECLINES?

The current loss of Neotropical species and populations are of an unprecedented quantity and rate. What are the ethical considerations involved in the global extinction of amphibians? What are we prepared to do as scientists, biodiversity managers, policy makers, and global citizens to halt and reverse these losses? What will future generations say when they realize we did little to safeguard these species even as we continued to study their biology? Based in part on the ongoing loss of amphibian biodiversity in Latin America, Minteer and Collins (in press) have proposed that a new discipline—Ecological Ethics—is needed to provide both an ethical framework and practical guidelines to guide decisions and actions when faced with such a loss. Here we provide a list of conservation priorities that may alleviate, or perhaps reverse some losses.

RESEARCH.—We require intensive biotic surveys of amphibians along elevational and latitudinal transects to describe the geographic distribution of the problem, identify potential causes, and prioritize conservation efforts. Similarly, we lack basic data on population size, fluctuations, and demography for virtually every Neotropical species in almost all areas. Museum specimens (Burrowes et al. 2004, Ron et al. 2003, Lips et al. 2004, Eterovick et al. 2005, Bustamante et al. 2005) and archived data (Drost & Fellers 1996) are excellent resources with which to quantify past declines and search for evidence of pathogens. In the case of Atelopus (La Marca et al. 2005), about half of the species were data deficient because sites had not been resurveyed recently. A similar situation exists for documenting the potential causes of decline at a particular site. The role of some factors (e.g., disease, habitat loss, and climate change) has been studied at numerous sites or for several Neotropical species, but the role of others (e.g., chemical contaminants) has never been investigated.

Field efforts should be coupled with a broad survey of the altitudinal and latitudinal distribution of B. dendrobatidis among amphibians. More research into the ecology of B. dendrobatidis is needed, including such basic and critical aspects of its natural history as how and where it survives and how long it can persist in the environment. The model produced by Ron (2005) might serve as a framework for setting research and management priorities to control the spread of this disease and to safeguard threatened amphibians. One of the highest priorities is to determine the means by which B. dendrobatidis moves among sites, species, and individuals. We also encourage the use of museum specimens combined with GIS technology (Graham et al. 2004) to determine the epidemiological patterns of B. dendrobatidis infection in Latin America.

Despite our knowledge of many aspects of amphibian biology (Duellman 2001, Savage 2002), basic ecological and natural history data are lacking for most tropical species, thus preventing detailed comparisons and metaanalyses. Additionally, little information exists on dispersal patterns, population connectivity, and physiological tolerances. Experiments on the physiology of Neotropical amphibians and their response to climate change (e.g., Ron 2005) and diseases would be especially useful.

CONSERVATION.—We should lobby for habitat protection, as habitat loss is the primary cause of amphibian loss. Buying land may be the most effective conservation option in Latin America, considering the social and economic problems these countries face. In Mexico (Parra-Olea et al. 2005) and Brazil (Eterovick et al. 2005), continued habitat loss is expected to threaten many upland species of amphibians.

Captive breeding can be an important part of protecting and reintroducing rare amphibians, and for those species experiencing enigmatic declines, infection by B. dendrobatidis, or climate change, this is the only option currently available. The National Amphibian Conservation Center at the Detroit Zoo, for example, maintains populations of endangered species such as Atelopus zeteki, the Golden Frog of Panama, for future reintroductions. However, for captive breeding to be effective in the long term, it must be accompanied with habitat preservation and threat management.

LEGAL AND POLITICAL CHALLENGES.—Where amphibian populations have been reduced due to commercial trade, better monitoring and regulation are needed. Some species of Atelopus have been collected for the pet trade in large numbers (La Marca et al. 2005), with no consensus of the impact of those actions. Where climate change has affected amphibian populations, governments must take steps to address these impacts, such as planning reserve systems to allow for predicted climate change (e.g., Pyke & Fischer 2005) or strengthening laws related to natural resource extraction (e.g., Parra-Olea et al. 2005).

MANAGEMENT PRIORITIES.—Special attention is needed to manage, remove, and prevent the spread of exotic pathogens (e.g., Ron 2005). Park officials need to institute measures to prevent the spread of diseases and exotic species by tourists and residents. We can reduce inadvertent spread of B. dendrobatidis by scientists to healthy sites by disinfecting lab and field gear with 10 percent chlorine bleach solution (www.nwhc.usgs.gov/research/amph_dc/sop_mailing.html). Successful removal of nonnative trout from lakes in the Sierra Nevada of California has resulted directly in the recovery of native Mountain Yellow-legged Frog populations (Rana muscosa) in these areas (Knapp et al. 2001, Vredenberg 2004). Similar efforts might be productive in areas of the Neotropics where trout have been introduced (La Marca & Reinhalter 1991).
COMMUNICATION AND COOPERATION.—A primary objective of RANA is to exchange information, ideas, methods, materials, and skills among labs, sites, and countries to promote cross-site and cross-species comparisons. Collaborative, international, multi-disciplinary projects such as those represented here can produce results from a broader region (Bustamante et al. 2005, Eterovick et al. 2005, La Marca et al. 2005), and can be more efficient in sharing information, skills, and materials (Parra-Olea et al. 2005). A multi-factorial approach to field studies is needed to understand how and why amphibian populations are declining and to detect interactions among key factors. A coordinated and diverse array of experts from many disciplines, including ecologists, systematists, biodiversity managers, and policy makers is needed to implement these findings and to communicate their importance to the global community.

CONCLUSIONS

The papers compiled in this special section have greatly expanded our concept of the geographic and taxonomic scale of amphibian population declines in the Neotropics based on a limited number of case studies. It can be difficult to produce a consensus on the status of many species and populations given the diversity, limited historical data, and natural variability of amphibian populations, and the relative inaccessibility of many sites. As a result, conclusions are often limited to only the most obvious or abundant species that have demonstrated the most dramatic declines (e.g., species of *Atelopus*). All these factors conspire to produce a gross underestimate of the problem and foster a general (but incorrect) perception—both among the public and other scientists—that amphibian declines are restricted to a certain number of isolated sites and species, that intervening regions have not been affected, that most declines are simply natural population fluctuations, and that few species have become extinct. Imagine the change in those perceptions and in our conservation priorities after seeing field data from just the dominant amphibians in major Neotropical ecoregions!

We have just begun studying the impacts of amphibian declines on ecosystem structure and function, but losses of the magnitude documented here are expected to produce cascading effects throughout aquatic (Vannote et al. 1980) and terrestrial food webs because of the sheer biomass of amphibians, and the linkages they form between aquatic and terrestrial habitats. Both top-down and bottom-up effects are predicted because some stages and species of amphibians may consume algae and sediments (e.g., Flecker et al. 1999, Solomon et al. 2004, Ranvestel et al. 2004), others consume invertebrates (including potential disease vectors), and still others serve as prey to both vertebrates (birds, mammals, snakes) and invertebrates.

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LITERATURE CITED


