Population Declines and Priorities for Amphibian Conservation in Latin America

BRUCE E. YOUNG,*†††† KAREN R. LIPS,† JAMIE K. REASER,‡ ROBERTO IBÁÑEZ,§ ANTONIO W. SALAS,** J. ROGELIO CEDEÑO,†† LUIS A. COLOMA,‡‡ SANTIAGO RON,‡‡ ENRIQUE LA MARCA,§§ JOHN R. MEYER,*** ANTONIO MUÑOZ,††† FEDERICO BOLAÑOS,‡‡‡ GERARDO CHAVES,‡‡‡ AND DAVID ROMO§§§

*The Association for Biodiversity Information, 1101 Wilson Boulevard, Arlington VA 22209, U.S.A.
†Department of Zoology, Southern Illinois University, Carbondale, IL 62901–6501, U.S.A.
‡Office of Ecology and Terrestrial Conservation, U.S. Department of State, Washington, D.C. 20520, U.S.A.
§Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Panama
**Museo de Historia Natural, Universidad Ricardo Palma, Avenida Benavides, cuadra 54, sin número, Lima - 33, Peru
††El Colegio de la Frontera Sur, Apartado Postal 424, Código Postal 77000, Chetumal, Quintana Roo, Mexíco
‡‡Pontificia Universidad Católica del Ecuador, Museo de Zoología, Avenida 12 de Octubre y Roca, Apartado 17–01–2184, Quito, Ecuador
§§Laboratorio de Biogeografía, Facultad de Ciencias Forestales y Ambientales, Universidad de los Andes, Mérida 5101–A, Venezuela
***Navajo Natural Heritage Program, P.O. Box 1480, Window Rock, AZ 86515, U.S.A.
†††El Colegio de la Frontera Sur, Apartado Postal 63, Carretera Panamericana y Periférico Sur, sin número, 29200 San Cristóbal de las Casas, Chiapas, Mexíco
‡‡‡Escuela de Biología, Universidad de Costa Rica, San Pedro, Costa Rica
§§§Colegio de Ciencias Ambientales, Universidad San Francisco de Quito, Casilla Postal 17-12-841, Quito, Ecuador

Abstract: *Although dramatic amphibian population declines have been reported worldwide, our understanding of the extent of the declines in Latin America, where amphibian diversity is high, is limited to a few well-documented studies. To better understand the geographic extent of declines, their possible causes, and the measures needed to improve Latin American scientists' ability to research the phenomenon and make effective management recommendations, we convened three regional workshops with 88 Latin American herpetologists and conservationists. Population declines are widespread in Latin America. At least 13 countries have experienced declines, and in 40 cases species are now thought to be extinct or extirpated in a country where they once occurred. Declines or extinctions have affected 30 genera and nine families of amphibians. Most declines have occurred in remote highlands, above 500 m in elevation in Central America and above 1000 m in the Andes. Most documented declines occurred in the 1980s. Of the possible causes studied to date, climate change appears to be important at one site and chytrid fungal disease has been identified at sites in three countries. Although many monitoring studies are currently underway in a variety of habitats, most studies are recent and of short duration. In a signed resolution, workshop participants called for greater collaboration and communication among scientists working in Latin America to understand the geographic extent of population declines and the distribution of possible causal factors. In situ conservation is important to protect habitats, but captive-rearing programs for species subject to imminent extinction are also needed. Better understanding of the taxonomy and natural history of amphibians and more funding for research and monitoring are critical to developing a scientific basis for management action to arrest and reverse population declines.*

††††*email bruce_young@abi.org*
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Disminución de Poblaciones y Prioridades Para la Conservación de Anfibios en Latinoamérica

Resumen: *A pesar de las dramáticas disminuciones en las poblaciones de anfibios que se han reportado a nivel mundial, nuestro conocimiento sobre la extensión de las disminuciones en Latinoamérica, donde la diversidad de anfibios es alta, se encuentra limitado a unos pocos estudios bien documentados. Para conocer mejor la extensión geográfica de las disminuciones, las posibles causas y las medidas necesarias para mejorar la capacidad de los científicos latinoamericanos para investigar el fenómeno y realizar recomendaciones de manejo efectivas, llevamos a cabo tres talleres regionales con 88 herpetólogos y conservacionistas latinoamericanos. Las disminuciones poblacionales están ampliamente distribuidas en Latinoamérica. Por lo menos 13 países han tenido disminuciones y en 40 casos las especies son ahora consideradas extintas o extirpadas en un país donde alguna vez existieron. Las disminuciones o extinciones han afectado a 30 géneros y nueve familias de anfibios. La mayoría de las disminuciones han ocurrido en áreas de más de 500 m de elevación en Centroamérica y de más de 1000 m en los Andes. La mayoría de las disminuciones documentadas ocurrieron en los años 1980. De las posibles causas estudiadas a la fecha, el cambio climático parece ser importante en uno de los sitios y la enfermedad causada por un hongo chítrido ha sido identificada en sitios de tres países. A pesar de que se estén llerando a cabo muchos estudios de monitoreo en una variedad de hábitats, la mayoría de los estudios son recientes y de corta duración. En una resolución firmada, los participantes de los talleres solicitaron una mayor colaboración y comunicación entre científicos que trabajan en Latinoaméica para conocer la extensión geográfica de las disminuciones poblacionales y la distribución de posibles factores causales. La conservación* in situ *es importante para proteger hábitats, pero los programas de producción en cautiverio de especies sujetas a una inminente extinción también son necesarios. Un mejor conocimiento de la taxonomía y la historia natural de los anfibios y un mayor financiamiento de la investigación y el monitoreo son críticos para desarrollar las bases científicas para llevar a cabo acciones de manejo que detengan o reviertan las disminuciones poblacionales observadas.*

Introduction

Like most terrestrial elements of biodiversity, amphibian diversity is severely threatened by habitat destruction (Sala et al. 2000). Yet, since 1989 we have known that amphibian populations are threatened by other incompletely understood factors even in areas without obviously altered habitats (Blaustein & Wake 1990; Reaser 1996). Scientists, primarily under the auspices of the Declining Amphibian Populations Task Force, have convened numerous meetings over the last decade to determine the causes of the mysterious amphibian population declines, defined here as rapid, substantial, and sustained reductions in population densities (Wake 1998; Carey et al. 1999). Through these meetings and published research reports, herpetologists have identified a set of probable factors responsible for the loss of amphibians (Table 1) and have demonstrated the scientific and political challenges to understanding ecological phenomena.

Although there is evidence that amphibian populations are declining on every continent where they occur, contributions to the study of the problem come primarily from scientists based in the United States, Europe, and Australia (Houlahan et al. 2000). Few efforts have been made to access the knowledge of herpetologists in the developing world to specifically address amphibian declines, despite recognition of this need (Wake 1998).

Latin America in particular harbors a highly diverse amphibian fauna, representing half of the world's total species richness (Duellman 1999). To date, international conservationists are aware of a few well-known declines, including substantial defaunation and probable extinction of the golden toad (*Bufo periglenes*) at Monteverde, Costa Rica, and die-offs of other species in Panama (Pounds & Crump 1994; Pounds et al. 1997, 1999; Lips 1998, 1999). Less well-publicized declines have also been reported in Honduras, Venezuela, Ecuador, and Brazil (Heyer et al. 1988; Weygoldt 1989; La Marca & Reinthaler 1991; Coloma 1995; Lötters 1996; La Marca & Lötters 1997; Wilson & McCranie 1998; Coloma et al. 2000; Wilson et al., unpublished data). Yet Latin America is vast, and its amphibian diversity is extraordinary. Are the few declines reported in the scientific literature isolated cases, or are more widespread declines going unreported? How much and what kinds of monitoring and inventory activity occurs in Latin America? What patterns do the declines show? Given what we know about the declines, what are the priorities for conservation of amphibians in the region?

To answer these questions, we need to collaborate extensively with researchers based in Latin America. These are the people who repeatedly return to the same collecting or sampling sites or who bring student field trips to the same sites year after year and, therefore, have the best perspectives on declines in their regions. Combining this knowledge with the findings of published studies focused on declines and the experience of field conservation practitioners is necessary to define effective actions needed to stem the loss of amphibian diversity in Latin America.

We report on the current understanding of amphibian declines presented by herpetologists at a series of three

Table 1. Probable and confirmed factors causing declines of amphibian populations worldwide.*

Factor	*Process(es)*	*Selected references*
Climate change	Temperature and precipitation patterns are altered so as to cause disruptions in micro- or macroclimate conditions.	Heyer et al. 1988; Stewart 1995; Laurance et al. 1996; Pounds et al. 1999
Habitat modification	Forests are cleared for settlement and agriculture; wetlands are drained and filled.	La Marca & Reinthaler 1991; Salas 1995; Fisher & Shaffer 1996
Habitat fragmentation	Roads, introduced species, and low pH dissect habitats, creating barriers to dispersal.	Jennings & Hayes 1985; Bradford et al. 1993
Introduced species	Introduced predators prey on or compete with native amphibians.	Jennings & Hayes 1985; Hayes & Jennings 1986; Bradford 1989; La Marca & Reinthaler 1991; Péfaur & Sierra 1999
UV-B radiation	UV-B damages and/or kills cells, causing egg mortality, retinal damage, lesions, and increased susceptibility to disease and low pH.	Blaustein et al. 1994*a*, 1998; Anzalone et al. 1998; Lizana & Pedraza 1998
Chemical contaminants	Toxicity can cause direct mortality of eggs and adults, mimic endocrine hormones, and reduce the prey base.	Harte & Hoffman 1989; Weygoldt 1989; Beebee et al. 1990; Sparling 1995
Acid precipitation and soil	Toxins create barriers to dispersal and cause high egg and larval mortality.	Harte & Hoffman 1989; Beebee et al. 1990; Sparling 1995
Disease	Disease often causes death in amphibians; what made amphibians susceptible to disease is often unknown.	Carey 1993; Kiesecker & Blaustein 1995; Jancovich et al. 1997; Berger et al. 1998, 2000; Lips 1998, 1999; Carey et al. 1999; Daszak et al. 1999; Mao et al. 1999
Trade	Amphibians are removed from the wild and traded internationally for the culinary, pet, medicinal, and biological supply markets.	Smith 1953; Gibbs et al. 1971; Jennings & Hayes 1985; Salas 1995; Gorzula 1996
Synergisms	Multiple factors can act together to cause mortality and sublethal effects.	Blaustein et al. 1994*b*; Long et al. 1995; Carey et al. 1999; Mao et al. 1999; Pounds et al. 1999

**The response to these factors varies among species and populations of amphibians.*

regional workshops in Latin America during November 1999 (for locations see acknowledgments section) and supplemented with other published data and information solicited from herpetologists unable to attend the workshops. To understand the amount of effort currently invested in field activities that might contribute to the detection of population declines, we summarize the characteristics of 118 monitoring projects undertaken by workshop participants. Based on these results and discussions held at the workshops (and enriched by participation from governmental natural-resource agencies and nongovernmental environmental organizations), we prioritized actions needed to enhance amphibian conservation efforts in the region. We hope that these findings will advance the understanding of patterns and trends in amphibian declines worldwide, that conservation biologists will identify areas in which they can share their expertise with Latin American colleagues, and that funding agencies will consider the needs of Latin American herpetologists when setting priorities for funding.

Status of Latin American Amphibian Populations

To paint as complete a picture as possible, we include information from a variety of sources. Some observations are based on less extensive data than others, so we divided the discussion into sections based on decreasing certainty. Spanish-language abstracts of individual presentations made at the workshops are archived on the Web (http://www.lternet.edu/la).

What We Know about Amphibian Population Declines in Latin America

Amphibian declines are widespread in Latin America, extending beyond the well-known cases in Central America. At least 13 countries in Latin America have experienced declines or extinctions of anuran populations over the past 20 years (Table 2; Fig. 1). In a total of 53 cases, species are now thought to be extinct or extirpated in a country where they once occurred. Declines or extinctions have affected 30 genera and nine families of amphibians. Most amphibian population declines in Latin America have been reported to have occurred in remote highlands (above 500 m elevation in Central America and above 1000 m in the Andes) and to have affected stream-associated species to a greater extent than terrestrial species. Lowland sites at which frog populations have been reported to decline have been affected by a variety of human activities.

Many of the affected populations were previously abundant and predictably encountered. For example, up until

Table 2. Reports of amphibian population declines in Latin America.

Country	*Site*	*Status**	*Genera affected*	*Timing of declines*	*Source*
Mexico	upland areas of Veracruz, Oaxaca, Guerrero, Chiapas	16 species with population declines	*Hyla, Plectrohyla*	early 1980s	J. Mendelson, personal communication
Guatemala	Montañas del Mico	3 species extinct	2 species of the *Eleutherodactylus rugulosus* group, *Hyla bromeliacia*	1985–1986	Campbell 1998, 1999
Honduras	Nombre de Dios	9 of 16 species affected, 4 extinct	*Atelophryniscus, Duellmanohyla, Eleutherodactylus, Plectrohyla, Rana*	early 1990s	Wilson & McCranie 1998; Wilson et al. 2001
Costa Rica	Monteverde (Cordillera de Tilarán)	20 of 50 species disappeared, one of which is extinct	*Agalychnis, Atelopus, Bufo, Cochranella, Eleuthero-dactylus, Hyla, Hyalino-batrachium, Rana*	1987–1988	Pounds & Crump 1994; Pounds et al. 1997, 1999
Costa Rica	Cordillera de Talamanca	26 species declining, 1 species extirpated from country; 14 of 20 species (Las Tablas site) and 21 of 31 species (Las Alturas site) disappeared; 1 sala-mander species in decline	*Agalychnis, Atelopus, Bolitoglossa, Bufo, Colostethus, Eleutherodactylus, Hyla, Phyllomedusa, Rana*	1980s	Lips & Donnelly 2002; Lips 1998, unpublished data; G. C. & F. B., un-published data
Panama	Cordillera de Talamanca	35 of 55 species from Fortuna disappeared from study area	*Atelopus, Bufo, Centrolene, Cochranella, Colostethus, Eleutherodactylus, Hya-linobatrachium, Hyla, Phyllomedusa, Rana*	1996–1997	Lips 1999, unpublished data
Puerto Rico	El Verde	3 species extinct, 6 declining	*Eleutherodactylus*	1974–1994	Joglar & Burrowes 1996; Hedges 1993
Dominican Republic	Cordillera Central	6 species extinct	*Bufo, Eleutherodactylus, Hyla*	1970–1990s	Hedges 1993
Venezuela	Andes	7 of 8 *Atelopus* species extinct or extirpated from country	*Aromobates, Atelopus, Colostethus, Nephelobates*	late 1980s	La Marca 1995; La Marca & Lötters 1997
Colombia	Serranía de Paraguas	local population die-off	*Centrolene, Colostethus, Eleutherodactylus, Gastrotheca*	1997	Lynch & Grant 1998
Ecuador	Andes	15 species extinct and 8 species declining	*Atelopus, Colostethus, Gastrotheca, Hyla, centrolenids, Nelsonophryne, Osornophryne, Telmatobius*	1980s	Coloma 1995; Coloma et al. 2000; L.C. & S.R., un-published data
Peru	coastal desert, Andes	8 species declining	*Atelopus, Batrachophrynus, Colostethus, Dendrobates, Telmatobius*	no data	Salas 1995; Salas & Jiménez, un-published data; Salas & Schulte, unpublished data
Brazil	Atlantic coastal forest	8 of 13 species extirpated from study area (Weygoldt); 5 of 63 species extirpated from study area (Heyer et al.); 1 montane species in sharp decline (Guix et al.)	*Adenomera, Centrolenella, Colostethus, Crosso-dactylus, Cycloramphus, Eleutherodactylus, Hylodes, Melanophryniscus, Ololygon* (= *Scinax*), *Phyllomedusa, Thoropa*	late 1970s to mid-1980s	Heyer et al. 1988; Weygoldt 1989; Guix et al. 1998
Chile	Andes	1 species declining	*Rhinoderma*	late 1980s to 1990s	M. Crump, un-published data

**We refer to species with small ranges (<50,000 km^2) as "extinct" if for at least 5 years researchers have repeatedly searched for and not seen the species in appropriate habitat during appropriate seasons and weather conditions; no wide-ranging species are reported here as extinct.*

Figure 1. Extent of reported amphibian declines in Latin America: black, countries with published declines; gray, countries with unpublished declines reported; white, countries with no reported declines.

the late 1970s *Atelopus carbonerensis* was locally common in certain areas of the Venezuelan Andes, with densities up to 5/m^2 (E.L.M., unpublished data). Sometime during the 1980s this and six other *Atelopus* species from the Venezuelan Andes became rare and then disappeared completely from areas where they were once common (La Marca & Reinthaler 1991; La Marca & Lötters 1997).

Most of these population declines appear to have occurred in the 1980s, although frog populations at some northern sites were declining in the 1970s, and declines at some central and southern sites were not evident until the 1990s (Table 2). Dramatic declines (loss of populations and species over 1-3 years) have been observed in Costa Rica, western Panama, Venezuela, and Ecuador.

Few researchers have solid evidence pointing to specific causes of the declines they have identified. Chytrid fungal infections have been diagnosed in frogs collected at sites associated with declines in Costa Rica, Panama, and Ecuador (Berger et al. 2000; Lips 1999, unpublished data). Although we know this fungus can kill amphibians (Longcore et al. 1999), little else is known about this newly discovered disease of frogs, so its contribution to population declines cannot be determined. Climate change is suspected to be at least partially responsible for declines at Monteverde, Costa Rica (Pounds et al. 1999). The causes of population declines are likely to be varied, so the fact that the other factors have not been studied (Table 1) does not preclude them from being important.

What We Suspect about Amphibian Population Declines in Latin America

Some species with either low population densities or life-history characteristics that make them difficult to detect (e.g., some salamander species and large egg-brooding frogs such as *Hemiphractus, Gastrotheca*) now appear to be missing from portions of their known ranges and may have been significantly affected. Unfortunately, the intensive studies needed to make this determination have not been conducted. Historical density estimates for these species are unavailable, so comparisons will be impossible.

Although hard evidence is lacking, herpetologists in Latin America suspect that one or more factors may play a role in decline of amphibian populations at remote, upland sites. Those factors include introduced plants and animals (especially pines [*Pinus* and *Cupressus* sp.], eucalyptids, salmonids, and bullfrogs [*Rana catesbeiana*]), disease, increases in UV-B radiation, climate change, and pesticide drift. Although ambient UV-B radiation can reduce the survival of developing eggs and larvae of frogs in tropical Australia (Broomhall et al. 2000), results of the only study of UV-B radiation in Latin America suggest no effects on the anurans *Pleurodema bufonina* and *Bufo variegatus* in southern Argentina (S. Fox, unpublished data). Many herpetologists believe that introduced species could be contributing directly (e.g., through predation) and indirectly (e.g., through disease transmission) to amphibian population declines.

What We Do Not Know about Amphibian Population Declines in Latin America

Herpetologists have yet to survey many regions in Latin America and describe the many new species expected, so we will never know how many species are being lost before becoming recognized by science. Taxonomists believe that most of the North American and West Indies species have been described, but 5-10% of the amphibians of Central America still remain undescribed (Campbell 1999). The undescribed fauna of South America is probably much larger (Duellman 1999, Fig. 1:3).

Most declines have been detected by repeated visits to sites by taxonomists on collecting trips (e.g., Coloma 1995; Lynch & Grant 1998). Relatively few declines have been detected by ecologists involved in long-term research at a site. Because of this, ecological and life-history data collected over the course of the decline are rare, and there is little information on which life-history stages are most commonly affected and the timing and duration of the declines.

Likewise, there is little information on the patterns and trends of the suspected threats throughout most of the region, or the mechanisms by which these factors cause amphibian population declines. Furthermore, it is unclear how or whether specific human activities could be contributing to amphibian declines in remote regions. These gaps in information make it difficult for people interested in conserving amphibians in Latin America to make effective management and policy decisions.

Finally, we know little about the possible effects of trade on amphibian populations in Latin America. This exploitation may be a serious threat to target taxa (e.g., many dendrobatids and *Atelopus* sp.), but whether it is more important than habitat destruction in causing declines is unknown and requires more study.

Amphibian Monitoring in Latin America

Our survey of workshop participants revealed widespread amphibian monitoring and inventory efforts in Latin America (Table 3). Although this list is not exhaustive and some regions such as southern South America are underrepresented, it provides a good indication of the status of research in this field. Virtually all major habitat types in Latin America have been monitored, including dry, coniferous, and humid forest; low-, middle-, and high-elevation forest; savannas, shrublands, and paramos; inundated forests and wetlands; swamps, marshes, ponds, lagoons, and streams; and disturbed and undisturbed habitats. Most studies record observations along a transect, although some studies make use of leaf-litter plots and drift fences (Table 3). Most studies involve both diurnal and nocturnal observations that were made both visually and acoustically.

Most studies are recent. The median year in which studies were begun is 1997. Only four sites, three in South America and one in Central America, can boast quantitative data from before 1990, the year the alarm about amphibian population declines was sounded. Data from these studies are written up, if at all, in theses and gray literature reports that are not easily accessible. Data from only five sites (5% of the total) have ever been published in peer-reviewed journals (Pearman et al. 1995; Lips 1998, 1999; Salas et al. 1999). Outside of this sample, we are aware of only four additional published studies from Latin America (Heyer et al. 1988; Weygoldt 1989; Rodríguez 1992; Duellman 1995). Thus, international analyses of amphibian declines typically include few sites and potentially underestimate the seriousness of population declines. For example, the comprehensive, worldwide compilation of amphibian monitoring data by Houlahan et al. (2000) listed only four Latin American studies.

Priorities for Action

Many challenges face herpetologists attempting to understand population declines and develop management guidelines for amphibian protection in Latin America. We list the priorities identified by researchers at the workshops, including research capacity needs. We summarize the most important recommendations in Table 4.

Distribution of Declines and Their Possible Causes

Our compilation of sites where population declines have been confirmed represents a small portion of Latin America (Table 2). Considering only montane regions, where declines appear to be most likely to occur, many more studies are needed to understand the geographic distribution of population declines. Mexico, with its extensive mountain systems, is woefully understudied. (Population-level research of lowland populations in southern Mexico, however, is well developed.) Central America, Costa Rica, and Panama are relatively well studied, but assessment of amphibian declines in montane areas of Guatemala and Honduras is only just beginning (Campbell 1998, 1999; Wilson & McCranie 1998; Meyer & Meerman 2001; Wilson et al., unpublished data). To our knowledge, the montane regions of Jamaica and Cuba

Table 3. Survey of monitoring and inventory sites in selected Latin American countries.

Country	*Number of sites*	*Years*	*Years with data (mean ± SD)*	*Sites using transects (%)*	*Sites using leaf-litter plots (%)*	*Sites using drift fences (%)*
Belize	32	1993–1999	1.6 ± 0.9	100	22	0
Colombia	1	1997–1998	2.0	100	100	0
Costa Rica	11	1990–1998	3.2 ± 3.9	100	27	0
Dominican Republic	2	1998–1999	1.0 ± 0.0	100	0	0
Ecuador	26	1986–1999	1.2 ± 0.6	100	23	0
Guatemala	2	1997–1999	2.0 ± 1.4	100	0	0
Honduras	1	1998	1.0	100	100	100
Mexico	18	1996–1999	1.7 ± 0.9	100	6	22
Panama	20	1976–1999	2.2 ± 2.5	50	15	5
Peru	1	1989–1993	5.0	100	100	0
Venezuela	4	1994–1999	2.5 ± 1.9	75	25	0

Table 4. Priorities for research and training in Latin America with respect to amphibian conservation.

Conclusions	*Recommendations*
Research priorities need to be established to provide resource managers and policymakers with information for decision making.	Determine the distribution and taxonomic extent of amphibian declines in association with the possible causative agents. Determine the ecology, natural history, and diseases of species in decline. Experiment to test causative agents.
Herpetologists need to collaborate with experts from other scientific disciplines such as ecology, limnology, toxicology, climatology.	Present talks on amphibian declines in a variety of scientific fora to raise awareness of the issue and identify collaborators.
Data collected related to declines need to be widely available.	Collaborate with the Declining Amphibian Populations Task Force on a declining amphibians database for Latin America.
Effectively managed systems of protected areas are the means for protecting amphibians from anthropogenic activities.	Grant protected status and enforcement to poorly protected species; this will require better national inventories and analysis of priority areas for conservation.
Some species have declined so precipitously that ex situ conservation and reintroduction may be needed to save them.	Collaborate with captive-breeding specialists, zoos, and aquariums to produce captive stocks and to maintain them and their habitats for future reintroductions.
Latin American scientific institutions need to be strengthened to increase the capacity of academic programs, methodological training, and voucher curation in the field of herpetology.	Expand international field-biology training programs (e.g., Organization for Tropical Studies, Smithsonian Institution) in Latin America.
Latin America needs appropriate infrastructure for herpetological collections, tissue banks, and laboratories.	Establish financial and technical support for museum collections, tissue banks, and herpetological laboratories.
Many regions of Latin America lack amphibian field guides and taxonomic keys.	Establish financial and institutional support for systematics, including publishing field guides and taxonomic keys.
Latin American herpetologists do not have adequate funds to support the priorities for research on amphibian declines.	Emphasize the global nature of issue and global responsibility. Promote international collaborative research and find innovative funding sources (e.g., ecotourism, biotechnology).
Latin American herpetologists need to make their research findings more widely available.	Use the Internet to disseminate information through various biodiversity-related listservers. Journals should publish manuscripts in Spanish and Portuguese in addition to English.
Latin American herpetologists need to effectively communicate and form alliances with diverse groups (e.g., nongovernmental organizations, politicians, social scientists) to improve the political process (especially funding and permits).	Promote effective communication through various means, including print, video, and internet sources, to various groups, including general public, students, politicians, and conservation organizations.

remain unstudied with respect to amphibian populations. In South America, large gaps occur in Colombia, where widespread security problems effectively prevent fieldwork. In addition, we know little about the status of amphibian populations in the southern Andean region of Peru, Chile, and Argentina. In all of these sites, we may be too late to initiate monitoring programs that will detect future declines. Here, revisitation of sites where previous collections have been made will provide the best available estimate of the persistence of populations (La Marca & Lötters 1997; Coloma et al. 2000). To facilitate future monitoring efforts, workshop participants wrote a monitoring protocol manual published in English and Spanish (Lips et al. 2001).

In addition, high priority must be given to understanding the geographic distribution of potential causal factors. At sites where faunal persistence is assessed, researchers must also collect information about climate change, land-use change, introduced species, sources of potential chemical contaminants, and diseases. Collaboration with experts in other disciplines, including ecology, toxicology, climatology, and epidemiology, is needed to better inform this research. Bioassays to detect the chytrid fungus are in development (L. Berger, unpublished data) and should be performed frequently given the growing evidence that chytridiomycosis is widespread globally and affects a diverse taxonomic distribution of hosts (Berger et al. 1998, 2000; Daszak et al. 1999).

The next step is to aggregate the data and their corresponding metadata in a manner that allows analysis of factors at sites regionwide (Michener et al. 1997). The Declining Amphibian Populations Task Force is aggregating these data on a global scale (Heyer 1999); all Latin American projects should be a part of this larger effort.

In Situ and Ex Situ Conservation

Because habitat destruction is the most pervasive threat to amphibian populations, effective biological reserves are vital to their conservation. Many species, however, especially in montane areas, are being decimated despite no obvious changes in their habitat. These cases, in which local extinction is imminent, justify the placement of some individuals in an emergency captive-rearing program with strict controls against the introduction of diseases or chemical contaminants. The reintroduction of amphibians into the wild can be difficult (Gent 1999), so these species may never be reestablished in their former habitats. For species with severe population reductions, tissue samples stored in appropriate conditions may aid future attempts to maintain genetic diversity.

Biology

To know how best to design monitoring studies, we need better information about the basic ecology and natural history of many species. For example, the egg and larval stages of many anurans are undescribed. Thus researchers often do not know how, when, or where to monitor species and will not be able to effectively manage wild or reintroduced populations. To obtain this information, Latin American herpetology students need more training opportunities in field methods and voucher curation. An exception is the Mayan forest region of Guatemala, Mexico, and Belize, where many well-trained herpetologists live and the amphibian fauna is well known. Over the past 4 years, a coordinated monitoring network called the Maya Forest Anuran Monitoring Project has formed to include 14 herpetologists monitoring 27 sites (Meyer 1998).

We need a better understanding of the taxonomy and nomenclature of the large and incompletely described diversity of amphibians in the Neotropics (Campbell 1999). New species are described regularly. Advances in molecular studies are allowing differentiation of problematic species groups. For example, studies of populations of *Eleutherodactylus diastema* in Costa Rica and Panama suggest the presence of at least five undescribed species, some of which co-occur (C. Jaramillo, unpublished data). As a result, taxonomy is unstable, making it difficult for scientists to name unambiguously the species they study. Lack of consensus among taxonomic authorities leads to situations where workers assign different names to the same taxonomic unit. More regional guides, such as those written by Duellman (1970), Rodríguez and Duellman (1994), Lee (1996), Meyer and Foster (1996), Campbell (1998), and Ibáñez et al. (1999), will improve consistency.

Funding for Research

More funding is urgently needed for study of amphibian declines in Latin America. Although most temperate-zone countries can afford to invest in well-trained staff and comprehensive protection of biological reserves, most tropical countries do not have the means to effectively protect biodiversity (Meffe & Carroll 1997). Conservation and management plans in tropical countries are often based on scant data and supported by little capital or infrastructure (Soulé 1991; Janzen 1994; Terborgh 1999). Funding that exists is rarely available over a long enough term to support meaningful monitoring. Few of the research activities proposed here will be possible without an infusion of new and consistent funding in the region. In response to this need, workshop participants drafted a resolution calling on policymakers and funding bodies to provide more support to amphibian conservation (Lips et al. 2000).

At the same time, we need creative approaches to calculating the economic value of healthy amphibian populations to society. Amphibians are a source of biochemicals, serve in pest control, are traded internationally, and serve many cultural functions (Jennings & Hayes 1985; Durrell 1986; Lee 1996; Reaser 1996). More funding through a variety of sources would be forthcoming if the true value of amphibians were appreciated in our society (Salas & Fachín 1997; Janzen 1999).

Communication

Better communication among scientists is necessary for researchers to build on existing knowledge. Latin American scientists traditionally do not place as much emphasis on publishing as do scientists in the United States, Europe, and Australia. They receive few professional rewards for publishing: promotions and salary increases are rarely tied to publishing activity. Thus, few Latin American–based journals are available in which to publish results, and much good work goes unpublished. Scarce funding prevents Latin American scientists from participating in international meetings, limiting their ability to (1) disseminate results, (2) establish collaborations that could result in influential publications, and (3) influence policy by becoming active in such organizations as the Society for Conservation Biology or the Declining Amphibian Populations Task Force. Reduced costs of membership in professional societies for people in developing countries and a willingness to publish articles in Spanish or Portuguese would also foster greater manuscript submissions by Latin American authors. For example, the journal *Biotropica*, which has lower membership rates for citizens of developing countries and accepts manuscripts in English, French, Portuguese, and Spanish, has experienced a large increase in submissions and publication of articles from Latin American authors (R. Marquis, personal communication).

Better communication with nongovernmental environmental organizations and decisionmakers can improve the political and funding climate for amphibian conservation. To begin to address this issue, Ecuadorian herpetologists formed a network complete with a list server (jambato@mail.usfq.edu.ec) and website (http://www.puce.edu.ec/Zoologia/declinac.html). This group joins an existing list server for Mayan forest biodiversity, including amphibian monitoring (selvamaya@listserv.vt.edu), and the Maya Forest Anuran Monitoring Project website (http://fwie.fw.vt.edu/mayamon/maya_home.html). Our understanding of amphibian declines will accelerate if herpetologists elsewhere in Latin America similarly create enhanced channels of communication.

Conclusions

We know amphibian declines are dramatic and widespread in Latin America (Table 2; Fig. 1). Monitoring programs are only just beginning (Table 3). Research priorities at this time are to map the distribution of population declines and potential causes. Once a substantive database is built, comprehensive, multisite comparisons will be the best tool with which to determine the relative importance of different causes. At the same time, we must address more pervasive problems, such as the lack of adequate natural-history information, taxonomic understanding, funding, and communication for the research to be fruitful.

The workshops we organized successfully catalyzed discussions among Latin Americans working on local cases of amphibian population declines. The three workshops were necessarily limited in the breadth of geographic coverage and in the depth of coverage into causal factors; as such they should be considered as only the first in a series of similar efforts. Biodiversity workshops such as these are a useful model for identifying priorities for other conservation issues in Latin America (e.g., del Río et al. 1999; Latta 2000).

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