Conservation Letter

CONSERVATION OF NEOTROPICAL HERPETOFAUNA: RESEARCH TRENDS AND CHALLENGES

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Abstract

The Neotropics harbor between 30-50% of the world's herpetofauna. However, little is known about the ecology and natural history of many species, making conservation strategies difficult to plan. After reviewing published papers on world herpetofauna conservation, it was shown that conservation biology has a low impact factor in scientific journals in comparison with other related disciplines such as evolutionary biology and ecology. Moreover, herpetology has one of the lowest impact factors within the biological sciences journals. The number of publications on amphibian and reptile conservation has increased in recent years; however, only 31% of the papers on herpetofaunal conservation have been published in high impact journals. There are many challenges to overcome in the conservation of the Neotropical herpetofauna. Uniform and stable taxonomic nomenclature is critical to avoid overestimation of species richness and diversity for conservation assessments, and in the context of legal proceedings. Herpetofaunal research needs to be conducted within the appropriate socio-political and economic framework, in order to effectively implement conservation area networks. It is important to reevaluate the role of protected area systems in ensuring the persistence of communities and populations, and to identify strategies and future conservation priorities, based on climate-change scenarios. Population and community studies at different spatial and temporal scales are necessary to understand herpetofauna responses to anthropogenic disturbances, habitat loss and fragmentation, edge and matrix effects, and their synergy with micro-climatic gradients, emergent diseases and shifting patterns of genetic diversity. One of the biggest challenges for herpetofaunal conservation science in the neotropics is to control habitat loss and increase landscape connectivity along altitudinal gradients, while at the same time control species invasion that alter native species' interactions and spread emergent diseases (e.g. Chytridiomycosis) facilitated by climate change.

Keywords: Conservation biology, herpetology, Latin America, threats, extinction, habitat fragmentation, policy.

Resumen
Los trópicos soportan entre el 30 y 50% de las especies del mundo. Sin embargo, poco se conoce sobre la ecología e historia natural de la mayor parte de estos organismos, por lo que es difícil planear estrategias para su conservación. A partir de una revisión de los trabajos publicados sobre la conservación de la herpetofauna mundial se determinó que el área de la conservación biológica presenta un bajo nivel de impacto en las publicaciones científicas en comparación con la biología evolutiva y la ecología. Así mismo, la herpetología como ciencia, tiene uno de los impactos más bajos entre las publicaciones científicas. El número de publicaciones sobre la conservación de los anfibios y reptiles ha tendido a aumentar en los últimos años. Sin embargo, sólo el 31% de los artículos de conservación de la herpetofauna han sido publicados en revistas de alto impacto. Aun existen muchos desafíos para asegurar la conservación de la herpetofauna neotropical, como: una nomenclatura taxonómica uniforme y estable para evitar sobreestimar la riqueza de especies en la conservación y para tener una legislación adecuada. También es imperante implementar una red de áreas para la conservación que incluya a los anfibios y reptiles, y que a su vez tenga en cuenta factores socio-políticos y económicos. Se debe reevaluar sistema de áreas protegidas neotropicales con base en escenarios de cambio climático y determinar la eficiencia de éstas para proteger a las comunidades y poblaciones identificando posibles estrategias y prioridades de conservación a futuro. Es necesario realizar más estudios poblacionales y de comunidades a diferentes escalas espaciales y temporales para entender la respuesta de la herpetofauna a la perturbación antropogénica, pérdida y fragmentación de hábitat, efectos de borde y de matriz y su sinergia con gradientes microclimáticos, enfermedades emergentes y pérdida de la diversidad genética. Uno de los mayores desafíos para la conservación de la herpetofauna es controlar la pérdida de hábitat e incrementar la conectividad a lo largo de gradientes altitudinales, a la vez que se controlan las especies invasoras que alteran las interacciones de las especies nativas y dispersan, con la ayuda del cambio climático, enfermedades emergentes.

Palabras Clave: Biología de la conservación, herpetología, Latinoamérica, amenazas, extinción, fragmentación del hábitat, políticas.

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Introduction

Biodiversity supports life on Earth, and human beings frequently depend on biodiversity to satisfy basic needs like food, refuge, medicine, combustibles, and industrial products [1]. Amphibians and reptiles are essential components of the Earth's biodiversity because they play integral roles in food webs as herbivores, predators, and prey, as well as connecting aquatic and terrestrial ecosystems [2]. There are currently 6347 amphibian and 8863 reptile species reported worldwide [3, 4], from this, 32.5% of all known amphibians and 22% of reptiles are endangered, and close to 122 amphibians and 22 reptile species currently are extinct from the wild [1, 5, 6, 7]. In North America alone, 21% of amphibian species and 12% of snakes and lizards are in threat of extinction, while 17% of these reptile species have not been categorized due to insufficient data [8, 9].

Tropical forests hold more than half of the Earth's species in only 7% of the continental surface (http://www.wri.org/publication/content/8190). Specifically, it is estimated that the Neotropics harbor 3046 amphibian species, almost 50% of the world's amphibians [10] and more than 3000 reptile species (500 Caribbean, 1060 Mesoamerican and 1560 South American reptiles), around 32% of the world's reptiles (P. Uetz pers. com. 2008). According to the IUCN's list of endangered species, in the continental Neotropics (17 countries in Middle and South America), 1685 amphibian and 296 reptile species are endangered. According to the IUCN [11], 40% of endangered, continental Neotropical amphibian species are found in only 5 genera (*Eleutherodactylus, Colostethus, Craugastor, Atelopus* and *Bolitoglossa*). Most endangered amphibian species have restricted geographic distributions and are associated with water bodies for larval development [12]. Crump [12], reports that the majority of species in decline are found among the families (names previous to new amphibian molecular phylogeny and classification) *Leptodactylidae, Bufonidae* and *Hylidae*. In the case of reptiles, 40% of endangered species are found within nine genera (*Anolis, Geophis, Abronia, Sceloporus, Tantilla, Rhadinaea, Lepidophyma, Ctenosaura, Kinosternon*; [11]) with *Abronia* being the most endangered genus in Mexico. Mexico is the only country in the Neotropics whose status of endangered reptiles has already been evaluated by the Global Reptile Assessmentdetermining that Mexican reptiles are in a better conservation status than other vertebrate groups [9].

The Global Amphibian Assessment (GAA) and the Global Reptile Assessment (GRA) have alerted the scientific community as to the extent of factors that threaten amphibian and reptile species survival. Some of the most important factors that have affected herpetofauna during the last three decades are: land use change (habitat deforestation, fragmentation and deterioration), emerging infectious diseases (such as the fungus that causes *Chytridiomycosis*), toxin release into the environment (and toxin-accumulation in trophic chains), overexploitation (by illegal trafficking or unmeasured scientific collecting), exotic species introduction (competitors or predators), and synergetic interactions with climatic change [10, 13 – 17]. In response to habitat changes and the combination of this threat with other factors, some amphibian and reptile species have undergone fluctuations in the duration of reproductive periods, loss of reproduction sites, loss of genetic diversity, changes in home ranges, population isolation due to the incapacity to cross anthropogenic matrix habitats, changes in individual growth rates and activity patterns, and changes in microhabitat use [12, 14, 18]. In fragmented environments, species with a greater degree of habitat specialization are more prone to extinction, as they are neither able to neither tolerate abrupt microclimatic changes nor move between patches of native forest [19, 20].

We do not yet know enough about current knowledge in neotropical herpetofauna. This study describes current trends of knowledge regarding the conservation of Neotropical amphibians and reptiles while also identifying some problems and challenges for herpetofaunal management and conservation planning.

Publications review on herpetofauna conservation biology.

Using the Thomson ISI Web of Science (http://apps.newisiknowledge.com/), I searched for papers published between 1996 and October of 2007 that contained, in the title or abstract, the words: amphibian OR reptile OR herpetofauna OR frog OR toad OR salamander OR snake OR lizard OR lacertilia OR turtle OR crocodilia OR caecilian OR skink. The search yielded a list of papers organized by field (such as authors, year, title, journal name, and country) that was used for this analysis. Literature was filtered through the ISI Web of Science to separate papers according to the biological scientific branches predetermined by Thompson's search engine and by country. The impact factor for each journal and scientific branch was determined from the last list of Journal Citation Reports for 2006 (http://admin-apps.isiknowledge.com/JCR/JCR). I found that from all sub-disciplines related to herpetology (n=12353 papers), only 5% of papers (n=618) made reference to conservation, and this subset of studies demonstrated a lower average impact factor (mean impact factor of 1.54; SD=1.4; Figure 1) compared with other sub-disciplines. The sub-field that showed the greatest impact factor within herpetology was evolutionary biology with a mean impact factor of 3.2 (SD=2.78) followed by ecology with 2.03 (SD=1.97). In general, the fact that the sub-disciplines of evolutionary biology and ecology each have relatively high impact factors might be because these sub-disciplines are covered by journals with no particular specialization of the kind of organisms and are read by a wide audience.

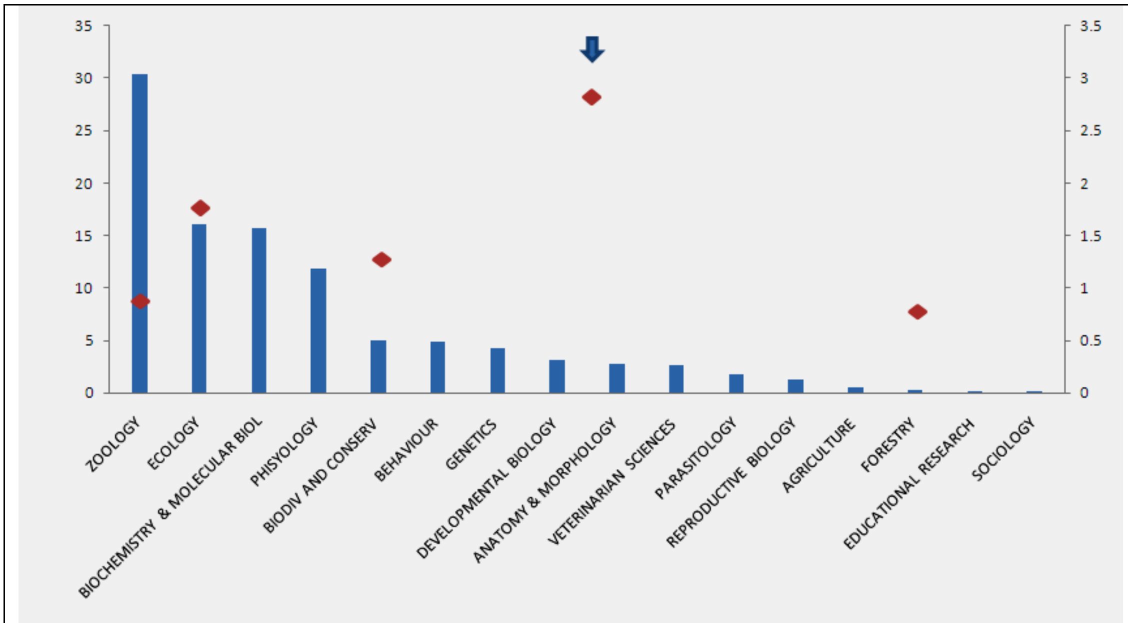

Fig. 1. Published scientific papers on amphibians and reptiles percent (blue columns; left Y-axis) and average journal impact factor (red diamonds, right Y-axis) in some biological sub-disciplines. The diamond under the arrow indicates the sub-discipline of evolutionary biology that is found between "developmental biology" and "anatomy and morphology" according to predetermined science topic categories of the ISI Web of Science and the Journal Citation Reports.

A total of 618 papers referring to amphibian and reptile conservation have been published in 45 journals. Only 31.5% of these papers have been published in two high impact journals for the whole discipline of biology (Figure 2): Biological Conservation (101 papers) and Conservation Biology (94 papers). These journals are among the five best ranked for conservation biology, with greatest journal's seniority and continuity at the international level [21]. This means that the scientific community is interested in publishing papers regarding biological conservation of amphibians and reptiles, however the rejection rate for these journals is frequently between 50 and 70% and thus, authors become discouraged and commonly submit their manuscripts to lower impact journals.

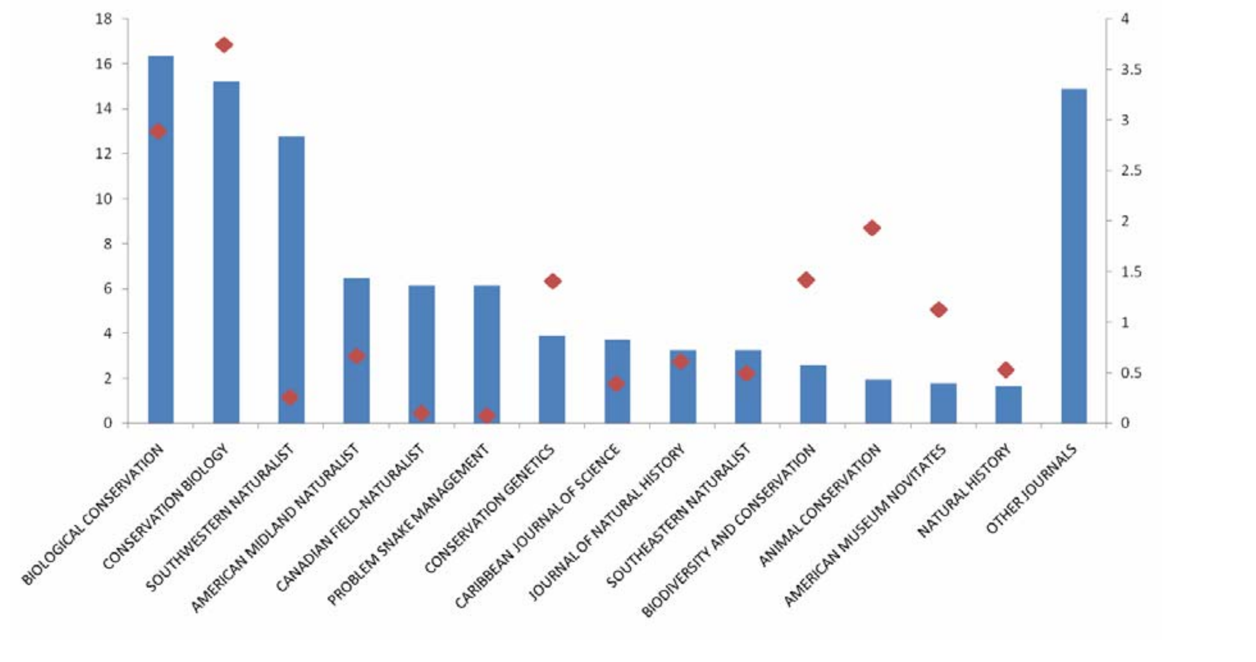

Fig. 2. Percentages of published scientific papers on amphibians and reptiles (blue columns; left Y-axis) and average journal impact factor (red diamonds, right Y-axis) in scientific journals focused on conservation biology.

Until present, there are only six publications specialized in herpetology that are indexed by Thompson ISI and have impact factor values (Herpetologica: 1.02; Herpetological Journal: 0.92; Herpetological Monographs: 0.89; Copeia: 0.84; Amphibia-Reptilia: 0.79; Journal of Herpetology: 0.79), showing a low worldwide impact factor in general (average of 0.87; SD=0.08) in comparison with specialized publications in ecology (average of 3.2; SD=1.97), conservation (average 2.03; SD=1.97) or mammalogy (0.97; SD=0.35). This indicates that the non-herpetological scientific community does not readily consult, read or cite journals specialized in herpetology. Also, the most highly-regarded journals in herpetology have a long turnover time (between 10 and 20 months) compared with those specialized in ecology and conservation (i.e. Biological Conservation, Conservation Biology, Biotropica, Ecological Applications), which respond or give an initial decision in one or two months, at most. This could be due to the enormous quantity of work generated in the field of herpetology and the small number of specialized journals in which to publish, with the impossible task of efficiently attending all submitted manuscripts and the fact that there are few herpetologists to do the difficult task of editing.

In conservation biology studies that entail field work there is often a significant time lapse (an average of 4 years) between data collection and the final publication of the paper [21]. Conservationists are currently demanding that journals give responses in a more rapid and efficient manner in order to quickly inform appropriate conservation-related actions [22, 23]. In the case of herpetological conservation there are recent publications on amphibian population declines [24], conservation of the Caribbean herpetofauna [25], and an increase in open access journals such as Tropical Conservation Science and Amphibian & Reptile Conservation. There is hope that new open access journals will provide efficient and accessible academic spaces for herpetologists to rapidly publish their results on the conservation of amphibians and reptiles.

Since 1996, there has been a slight increase in the publication of scientific papers on amphibian and reptile conservation (Spearman coefficient R=65.5%; p=0.021) with an average of 52.3 papers per year in the last decade. Years with the highest number of publications are: 1999 (63 papers), 2002 (57 papers), 2003 (69 papers) and 2006 (66 papers; Figure 3). The publication rate for manuscripts in Neotropical countries that have a conservation biology focus has increased from 2% in 1984 to 15% in 2004 [26]. While the trend in papers focused on conservation biology in Europe, has been decreasing [26].

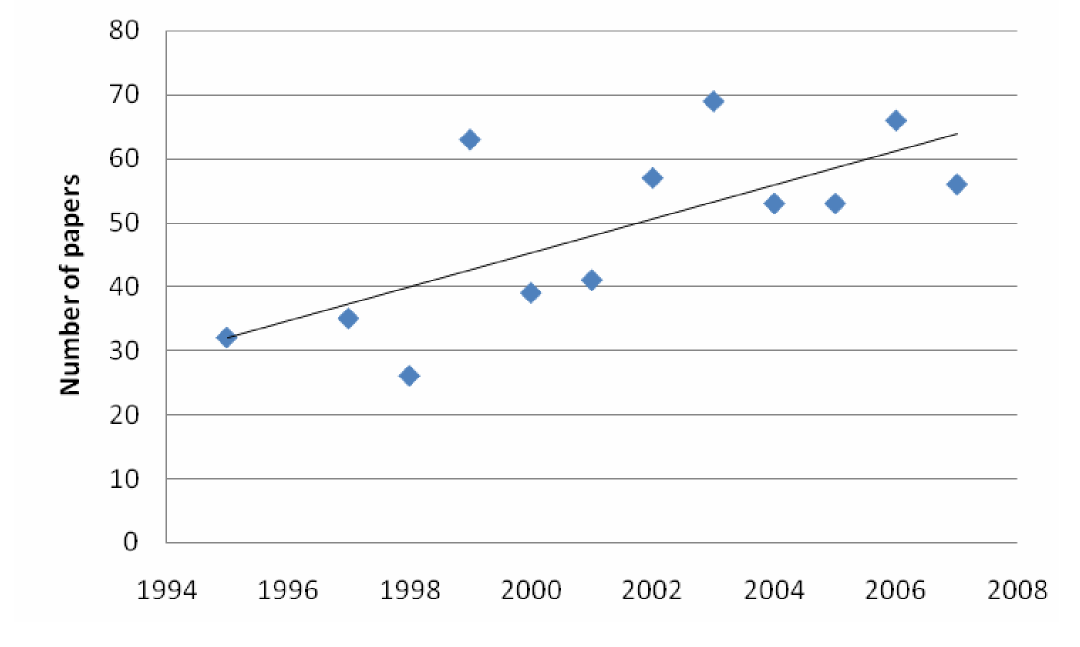

Fig. 3. Number of scientific papers in world conservation of amphibians and reptiles during the last decade.

From the 1453 authors that have published papers on amphibian and reptile conservation, the individuals that have made the most significant contributions (3% of total) are Goldberg, S.R., Bursey, C.R., Shine, R., Chiszar, D., Hayashi, Y., and Blaustein, A.R. This demonstrates a wide diversity of authors (with an average of 1.22 papers per author) and the lack of a predominant author or author-group in amphibian and reptile conservation. In contrast, the Neotropical countries that have the richest herpetofaunas have produced only 244 scientific papers written in English and published in journals detected by the Thomson ISI Web of Science (Figure 4).

Of the Neotropical countries that have the largest numbers of amphibian and reptile species, Brazil and Mexico published the greatest number of manuscripts with a conservation biology focus [26]. However, these numbers are not encouraging due to the fact that Brazil has published only 1% of the conservation biology literature in the world [26]. In many cases, the research from Neotropical countries remains hidden in theses, technical reports (i.e. grey literature) and scientific papers in local literature written in Spanish or Portuguese that is not available on highly used indexed academic search engines (i.e. ISI Web of Science, Bioone, Science direct, Blackwell-Synergy). Taking into account that Spanish-speakers represent 8% and Portuguese 4% of the world's population, it is logical that a researcher who is not a native English speaker experiences difficulty in gaining access to this information. However, every country has their own scientific journals of high local impact that probably have more impact on the conservation of these regions than papers in English published in international journals [26]. Therefore, it is important that researchers disseminate information at multiple levels: local (pamphlets, workshops, and books), national (scientific papers in local journals written in the county's language and through national conference proceedings) and international (high-impact journals written in English and through international conference proceedings). Only via a more thorough distribution of information is it possible to reach different sectors of society to generate interest, solicit necessary financial support and provide urgently needed data to conservationists, local NGOs, and politicians. Unfortunately, many Latin America's universities do not stimulate their own researchers to disseminate the results of their investigations at a local level, rewarding only the international publications. In addition, papers written by authors from countries where English is a national language have a higher citation rate and probability of acceptance than do papers written by authors from non-native English speaking countries [27, 28].

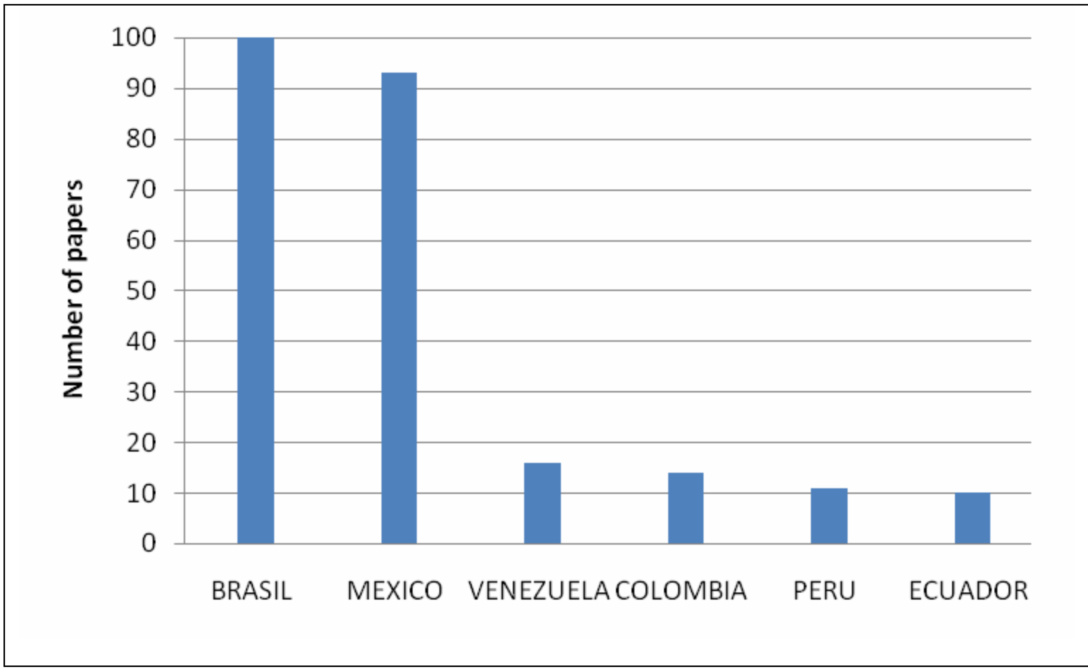

Fig. 4. Number of scientific papers in amphibian and reptile conservation per country in the Neotropical realm.

Science generated in English speaking countries must enrich tropical conservation science by consulting and citing the literature generated in Neotropical countries. Modifications need to be carried out within the publication process to address these two problems: it's imperative that Latin American authors publish more papers of international importance in English, but it is also important that researchers who are interested in work towards the conservation of Neotropical species learn Spanish and/or Portuguese in order to use and understand data in local literature. In Latin America there some excellent academic resources such as: SCIELO (http://www.scielo.org/), an on-line scientific library; LATINDEX (http://www.latindex.unam.mx/), a regional on-line information system with a search engine (http://redalyc.uaemex.mx/) for Hispanic scientific journals that includes more than 456 scientific journals from Latin-America, the Caribbean, Spain, and Portugal; CAPES (http://www.periodicos.capes.gov.br/portugues/index.jsp), that includes all major Brazilian science journals; and the ScienTI (http://www.scienti.net/) network, that includes 12 countries and attempts to generate standardized public information sources for researchers' Curriculum Vitae, research groups, and Hispanic institutions in general.

Due to the high local impact of non-English journals [26], it is important that the ISI WEB of SCIENCE reformulate their system for assigning impact factors at a regional scale for Latin American Journals, with the goal that: (a) they will be more easily detected by searches conducted within international institutions, (b) they can be taken into account to enrich tropical conservation science, and (c) Latin American universities encourage their researchers to disseminate information and data at local levels.

Challenges for herpetofauna conservation

Natural landscapes have been converted into semi-natural landscapes that reduce habitat quality and result in the loss of connectivity between patches of suitable habitat, reduced size of native habitat fragments, and edge effects [20, 29-32]. This in turn causes the extinction of individual species and functional groups (i.e. defaunation) which may precipitate extinction cascades throughout the food chain [29-32]. It is known that habitat loss is the principal cause of species extinction and affects 89% of amphibians on the American continent [10, 15]. In spite of being at high risk of extinction, amphibians and reptiles are the terrestrial vertebrate groups least studied in the world, with only 5 and 2.5% respectively, of the total number of studies conducted on vertebrates and the effects of habitat loss [18, 26]. There are also a reduced number of studies on consequences of anthropogenic effects and land use changes for herpetofauna in the Neotropics (2 studies in the sub-tropics and 17 in the tropics) [18].

In Neotropical countries, it is impossible to protect all areas that should be designated for biodiversity conservation and management due to agricultural development, accelerated population growth and problematical social, cultural, economic and political aspects (i.e. poverty, illiteracy, drug trafficking etc) [16, 33-34]. The current global network of protected areas covers 12% of the Earth's land, but is not sufficient as it leaves at least 11633 vertebrate species unprotected [35]. In many regions, reserves have been established in places with little productive or economic value and have frequently been declared for reasons other than the biodiversity they harbor (i.e. *ad hoc* reserves [36]). The systematic prioritization of conservation areas should be based on solid criteria such as complementarity, rarity, endemism and irreplaceability, but also including other social, political, legislative, and economic factors [36].

In diverse and complex regions like the Neotropics, it is necessary to have clear ecological and natural history criteria to inform the systematic selection of conservation areas. For example, the Neotropics host 54% of the 39 known amphibian reproductive modes, and each type of reproductive mode determines morphological and ethological adaptations which in turn determine the use of particular habitats and microhabitat [33, 37]. The reproductive modes of amphibians have proved to be an efficient criterion for the selection of priority areas, reflecting species natural history and degree of endemism [10, 38]. The selection of conservation areas should include multiple groups that maximize biodiversity representation [36]. However, and in despite their being key biodiversity components, amphibians and reptiles are systematically underrepresented in international conservation plans [16, 39].

Systematics and taxonomy are essential tools for improving biodiversity knowledge, and identifying and protecting endangered populations [40]. At present with the renaissance of systematic biology [41] species' molecular phylogenies have widened the gap between taxonomic authorities and conservationists because of the complex nature of amphibian and reptile taxonomies. Minton [40] discussed some examples of how some taxonomic problems can be confused with problems regarding amphibian status and conservation. Constant taxonomic name changes for various species discourage conservationists from working with herpetofauna. Herpetofauna are not commonly used in systematic conservation planning as a surrogate for biodiversity [39] partly because the historical geographic registers and older scientific works are not available to non-experts because they don't understand the complex and unstable systematic positions of this group. The constant taxonomic changes can also generate overestimation of amphibian and reptile richness as NGO and governmental databases are not necessarily managed by herpetologists and may contain the same species with different names (synonyms). In addition, hotspots for richness and endemism might change drastically depending on whether they are founded on the biological species or phylogenic species concept [42]. The prioritization of conservation areas should be developed for evaluated focal groups of amphibians and reptiles in collaboration with taxonomic experts.

The field of conservation biology has increased at an exponential rate in the last decade [26]. However, there is a clear separation between conservation biology within the academic environment and conservation management and action outside of academics [43]. Conservation biology research in the academic environment is very theoretical and locally biased towards organisms or habitats. Academic-based conservation biology research is rarely coordinated with the social sciences which render ecological scientific research of limited relevance to "on-the-ground" conservation [21]. There is a large gap between theoretical conservation biology research and management and application [21]. For amphibian and reptile conservation in the Neotropics, it is necessary to carry out multidisciplinary studies that have complementarity between herpetological research and other disciplines (i.e. sociology, education, anthropology, veterinary, microbiology, economy, and law), at the continental level (to elucidate general patterns), country level (to establish national priorities), regional level (to focus on priority locations for research and conservation) and local level (to finally implement conservation plans). We must connect *in situ* and *ex situ* conservation biology with social understanding and participation, so that scientific studies will be taken into account by local producers, decision makers and politicians. Meanwhile a change in farming livestock production systems can stimulate environmental heterogeneity in fragmented landscapes using mixed production methods (i.e. shaded coffee plantations) [44].

There are currently various programs that compile, extend, and support research and protection for endangered amphibians: Global Amphibian Assessment (GAA), Amphibian Conservation Action Plan (ACAP), Amphibia web, World Association of Zoos and Aquariums (WAZA), NatureServe, Amphibian Ark and Long Term Ecological Research, among others (for a complete list of institutions working on the decline of amphibians and their conservation see: http://amphibiaweb.org/resources/decline_resources.html). These organizations continue to grow at an encouraging rate during 2008 because of the celebration of the "international year of the frog" (WAZA). In contrast, several observed declines in reptile populations illustrate that their conservation status may be similar to that of amphibians yet with proportionally far less attention and weaker support for research, management and conservation that is focused principally on snakes and lizards [14, 16, 45-

46]. The Global Reptile Assessment (GRA) has been poorly developed, in spite of the program beginning in 2004, only 6% of the world's species have been evaluated, with preference towards crocodiles, turtles, iguanas and tuataras. This program should be a priority, in order to increase scientific research on Neotropical reptiles. While we do not know the basic population ecology for the majority of reptile species (lizards and snakes), we are unable to quantify the real extent of decline in Neotropical species.

The lack of interest for reptile-focused research could be due to the fact that they are organisms with cryptic habits, small population sizes and are more difficult to find than other vertebrate groups when in the field [14, 17]. In addition, humans instinctively fear reptiles [13, 47], with the consequent reaction of most of the people to eliminate, rather than study them [17]. Studies on the systematics and taxonomy of reptiles have been conducted but very little is known about their ecology and natural history.

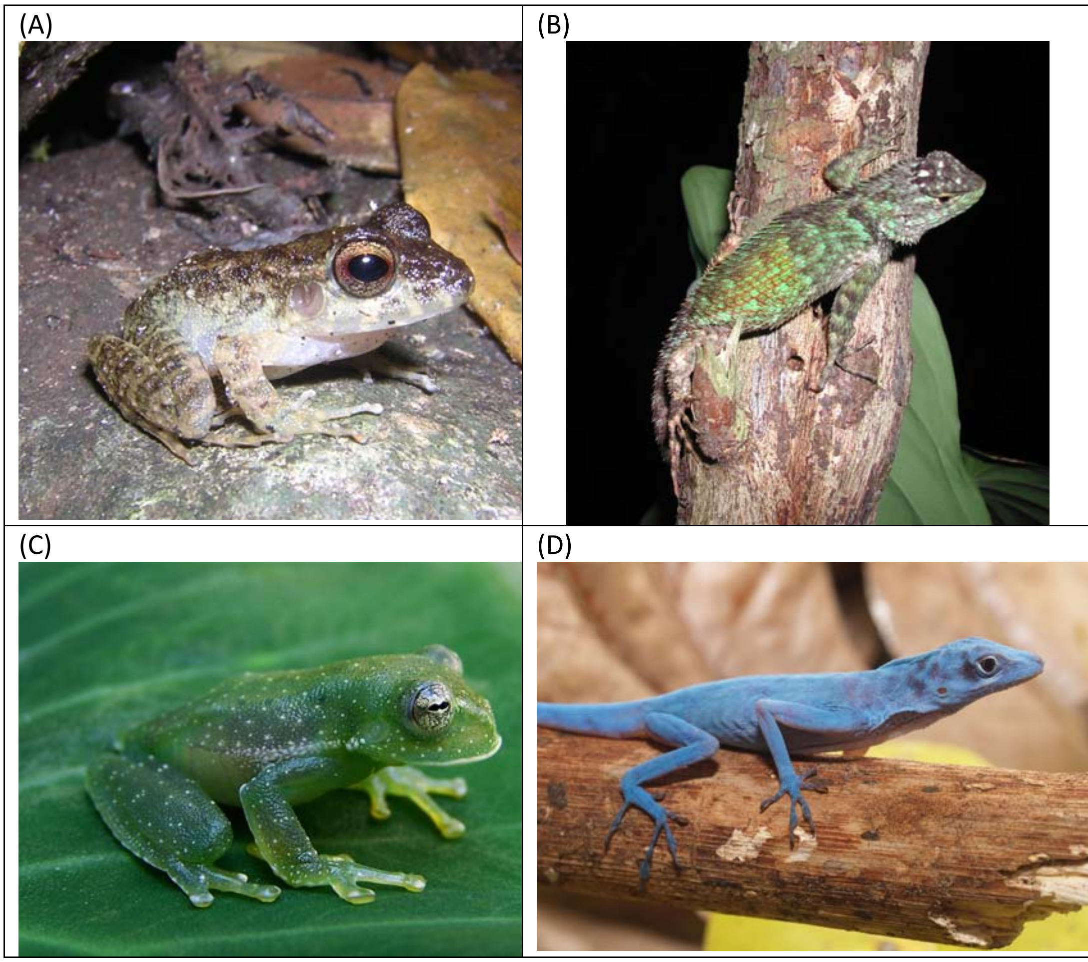

Fig. 5. Neotropical herpetofauna included in the IUCN's red list of threatened species. (A) *Craugastor berkenbuschii* (Near Threatened, Mexico), (B) *Sceloporus salvini* (Data Deficient, Mexico), (C) *Cochranella daidalea* (Vulnerable, Colombia; Photograph by M. Rada), (Photographs by J.N. Urbina-Cardona), (D) *Anolis gorgonae* (at risk of extinction, Gorgona island, Colombia; Photograph by M.M. Ramos).

Implications for conservation

Even in fragmented landscapes, we still have time to save some critical habitats for species conservation through systematic conservation planning (see [36, 48]). To take action for herpetofaunal conservation it is necessary to initiate and maintain homogeneous and stable nomenclature to avoid species richness overestimation and to be able to generate appropriate legislation for conservation. It is necessary to quantify viable population sizes, phylogenetic patterns, home ranges, geographical distributions and population structure of endemics, rare, and disturbance-sensitive species. Once we have identified as many endangered species as possible, we need to establish priorities to evaluate whether current protected areas include those species' distributions, and whether deforestation is the principle driver of habitat loss. These selection criteria should be complemented with social participation, including decision makers who promote and understand socioeconomic, ethic, and budget related issues so that conservation areas can be possible at a local level [34].

A. Future herpetofauna research projects in Neotropics should focus on:

-Standardized, continuous and long term ecological studies to detect population fluctuations and changes in species composition between climatic seasons, years and decades.

-Research on presence, prevalence, and extension of chytridiomycosis, as well as in the ecology of this fungus in the field: Behavioral changes between climatic seasons, development along altitudinal gradients, and response to anthropogenic disturbance, habitat loss, edge effects, and climatic changes.

-Taxonomic inventories in remote places far from highways and human settlements, which discover new species and define changes in species' geographical distributions.

-Identify sensitive groups and endangered populations based on population and genetic studies. Define the dynamics between hybridization and genetic variation with isolation and bottlenecks, within the parameters of species demographics (i.e. effective population sizes, age and sex structure) that inhabit highly fragmented environments [49].

-Studies to identify geographical patterns of species richness, complementarity, endemism, rarity, and degree of threat based on predictive (niche based) distribution models, which allow standardized geographical layers of Neotropical species' occurrence probability and their response to environmental change.

-*Ex situ* conservation in zoos or research institution as a complementary strategy for maintenance of species populations with a higher degree of threat [10], and to generate attitude changes towards increasing society's awareness as to the importance of preserving herpetofauna [13]. Reproduction in captivity requires more research due to the complex relationship between microhabitat, diet, and environmental gradients and reproductive modes (in the case of amphibians), in addition to the difficulties and consequences that species reintroduction implies in natural environments (i.e. zoonosis).

-Update amphibian and reptile IUCN's threat categories and national laws according to new validated taxonomy and their conservation status in protected areas.

-Standardize research design and sampling methods in order to avoid pseudo-replicates, compare results and sample at distinct spatial scales: microhabitat, habitat, habitat gradients (i.e. edge effects, altitudinal gradients) and entire landscapes. While scientific journals on ecology and conservation continue to favor research with complicated and innovative methods, this process impedes the development of a standardized protocol for herpetofauna sampling and analysis to identify clear general patterns.

-Report and share detailed geographic positions for collection sites so they can be used in future conservation biology studies. Describe methods in detail (i.e. replicates, repetitions, and seasons) and always report the capture effort (man-hours, trap-nights), and the basic descriptive statistics to be able to carry out robust future meta-analysis in the search of general patterns [18]. Although, in the case of endangered and highly-prized species, it's better to maintain species' localities in secret to avoid overexploitation by breeders and traders (J. Jacobs *com. pers.* 2008).

-Determine functional groups of herpetofauna that reflect species natural history or their response to disturbance [20, 38]. Evaluate species composition and abundance patterns to understand the relationship between the herpetofauna and environmental, spatial, and disturbance or succession gradients [20, 50-51].

-Sample tissues of rare or micro-endemic species for future ecological (i.e. dispersion, and population structure and size) and evolutionary studies, which can enrich conservation efforts [16].

B. Resources needed to improve research on Neotropical herpetofauna are:

Free servers that contain databases of geographical registers with standardized taxonomy and without duplicate registers. Authorities such as HerpNet (http://www.herpnet.org/), Global Biodiversity Information Facility (http://data.gbif.org/) and Inter-American Biodiversity Information Network (http://www.iabin.net/), that administrate this kind of database should make a plea to all museums, research institutions, governmental departments and NGOs to digitize and share their geographical registers to generate one large, standardized and refined database. Within each database it's important to develop a search engine that includes and detects all the possible taxonomic synonymies of a species. Conservation-applied research that uses geographical species distribution models can work rely on the cleanest and most accurate data in order to implement realistic conservation management plans.

One of the great limitations for Neotropical conservation is the lack of development of free GIS applications with less than 1km resolution for the entire continent, as these applications and geographic layers should be provided at zero cost by National Governments. It is necessary to have layers of political borders, detailed land use that can differentiate anthropogenic areas (agricultural lands, pastures and human infrastructure) from forests with slight native vegetative cover (such as seasonal dry forest or natural savannas), hydrological units (rivers, streams, lakes, springs, wells) digital orthophotos, satellite images, future climate scenarios, deforestation and socio-economical patterns. With this information, a robust GAP analysis can be carried out at the continental level and generate predictive maps of species distribution.

Finally, it is necessary to generate a worldwide (open) group of researchers, conservationists and interested educators on amphibian and reptile conservation to be able to interact, share ideas and publications, collaborate on projects and secure financing.

I have identified some patterns and challenges for Neotropical herpetofauna. If gaps continue to persist in knowledge of species' natural history and disagreement on taxonomic status: (a) there will be no consensus on species' threat status (mainly reptiles), to determine which species should be protected or managed [13], (b) there will be disagreement regarding the geographical scale of research and in the use of biodiversity surrogates or functionality of protected areas in climatic change scenarios.

Amphibian and reptile survival and the ecosystems that harbor these species are more vulnerable to extinction with each passing moment while science continues to have a limited impact on the implementation of conservation plans. The most important challenges facing conservation science are to reduce the spread of species invasion and emergent diseases (i.e. Chytridiomycosis) while increasing landscape connectivity (i.e. altitudinal gradients), to give the opportunity for amphibians and reptiles to adjust their home ranges in the face of rapid climate change.

C. Policy requirements from academic experiences:

-Educate policymakers on the value of amphibians and reptiles and the environmental services they provide to humanity [7]. At the same time, educate the scientific community as to how policymakers use scientific research findings when implementing conservation plans.

- Due to constant changes in amphibians and reptiles' taxonomy, it is urgent that taxonomists interact directly with NGO's and politicians to strengthen laws and regulations (hunting, sale and possession of neotropical herpetofauna) according to the new and established taxonomic status of each species.

-Constant updating of amphibian and reptile IUCN threat categories. Within the IUCN database include categories with information about a population's phylogenetic diversity to identify highly threatened and genetically important populations to be conserved, mitigating the loss of genetic diversity [52].

- Latin American countries have some of the best environmental regulations in the world, but many of these laws are not enforced in real scenarios. The Neotropics doesn't need more laws but requires that governments ensure that existing laws are actually enforced. Field scientists must review, and put in real context legislation about natural habitat deforestation, water contamination, illegal trade, overexploitation by local communities, over-collecting by scientists, and introduction (or translocation) of invasive species.

-Local governments should request private institutions (i.e. petroleum and building industries) and consulting firms, to make public and publish (in refereed journals) the information contained in technical reports as part of environmental impact assessments [53].

- Improve environmental education regarding the value of ecosystem services, benefits of recycling, threat of climate change, deforestation, species introduction, contamination and water waste in all schools, universities and governments and broadcast this information in the media (TV, newspaper and radio publicity) to reach as wide an audience as possible.

- Biological conservation is in the hands of local people and regional institutions (i.e. regional autonomous corporations, National Environmental Ministries, NGOs). Scientists have the responsibility to help these authorities to identify amphibians and reptiles in order to apply laws in the field (illegal trade, over-harvesting, translocation and excessive scientific collecting of wild species). Universities and research institutions must take on the responsibility to organize workshops and create practical field guides for identification of threatened species, and share this knowledge with local institutions and (bus terminals and airports) customs authorities.

-Some of the greatest scientific, economic and political challenges for the herpetofauna conservation are the control of habitat loss and species invasion alteration of native species interactions and spread of infections (i.e. chytrid fungus) into conserved natural habitats, especially where facilitated by climate change.

D. Practical Conservation Measures:

- Introduced animals (for pet trade, plague control or food) should be quarantined and examined for all known amphibian and reptilian diseases, including chytrid fungus [10].

- Field biologists must follow the protocols for clothes and equipment hygiene in the field when changing from surveyed habitat or altitudinal gradient to minimize risks of the spread of emergent diseases' [7, 54].

- Field biologists must have the ethical responsibility to avoid marking threatened populations with invasive techniques (such as toe clipping) and avoid over-collecting specimens when the use of photograph vouchers is acceptable.

- Publish research results in local and international scientific journals and distribute the information in scientific meetings, public libraries (www.conserveonline.org, www.2collab.com), non-scientific workshops and to the media.

- Encourage local people to maintain live fences and isolated trees in the agricultural lands to maintain some native vegetation that will help the regeneration of the contiguous forest (following [55, 56]).

- Within the forested areas, maintain large trees that provide dense canopy cover, deep cover of leaf litter, high relative humidity and low temperature, to buffer the environmental effects of habitat edges and the invasion of species from the matrix [20, 51].

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