New Amphibians and Global Conservation: A Boost in Species Discoveries in a Highly Endangered Vertebrate Group

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Amphibians are characterized both by a strongly increasing number of newly discovered species and by a high degree of decline. The observed increase in species numbers, over 25 percent in 11 years, is largely due to the intensified exploration of tropical areas and the application of more efficient techniques such as bioacoustics and molecular genetics, rather than to the elevation of subspecies to species rank or the distinction of species that were formerly considered synonymous. In the mantellid frogs of Madagascar, the many species newly described between 1992 and 2004 were as genetically divergent as those described in previous research periods, and most had not been collected previously, corroborating the lack of "taxonomic inflation" in this vertebrate class. Taxonomic exploration is still desperately needed to avoid misinterpretations in global conservation policy.

Keywords: taxonomy, new species, genetic divergences, Madagascar, biodiversity

Despite the notorious underfunding of taxonomy, the development of new analytical tools, especially molecular genetics, has led to acceleration in the recognition of new species of organisms, and the possibility of completion of a global biodiversity survey has been anticipated within one human generation (Wilson 2004). Among vertebrates, amphibians are a class in which numbers of recognized species have increased enormously in the past decades (Glaw and Köhler 1998, AmphibiaWeb 2004, Dubois 2005). The absolute number of recognized amphibian species was 4533 at the end of 1992 (Duellman 1993, Glaw et al. 1998) and 5723 by the end of 2003 (AmphibiaWeb 2004, Frost 2004), an increase of 26.3 percent in 11 years.

Nonetheless, amphibians are suffering severe declines (Wake 1991). A recent global assessment (Stuart et al. 2004) classified all known species according to their level of threat using IUCN Red List criteria. With at least 32.5 percent of amphibian species globally threatened, amphibians are declining much more rapidly than either birds or mammals.

One may ask why there are so many species discoveries when amphibians are declining (Hanken 1999). In a recent contribution to the literature on this question in primates and birds, Isaac and colleagues (2004) state that the increase in recognized species numbers is "due mostly to taxonomic inflation, where known subspecies are raised to species as a result in a change in species concept, rather than to new discoveries." Their opinion article provides a number of important thoughts about the impact of taxonomic schemes on conservation. However, the statement quoted above cannot be applied to all the groups and may strengthen a tendency to neglect the need for taxonomic exploration.

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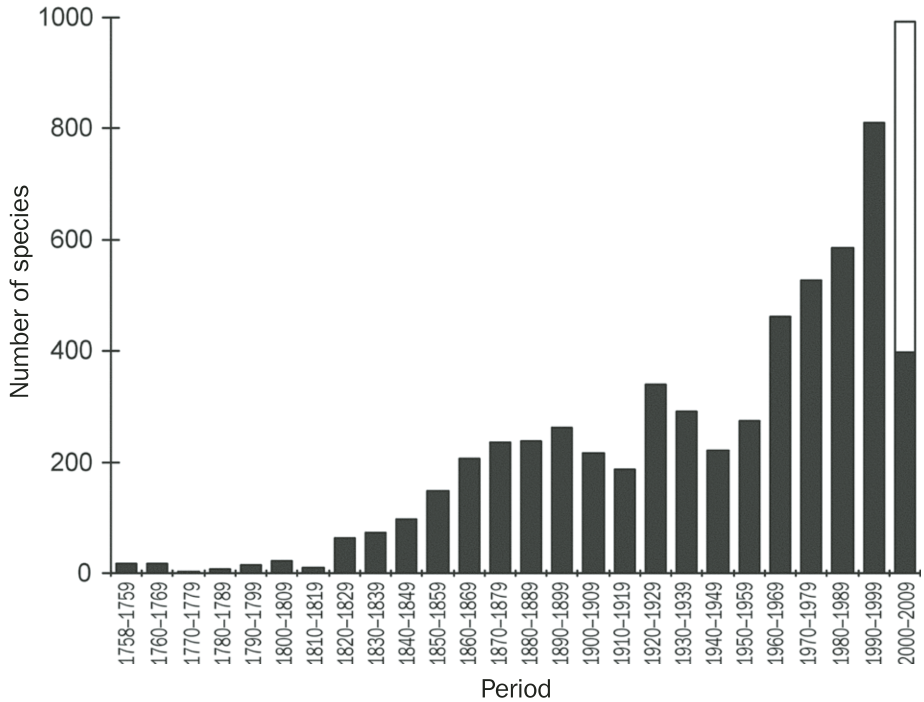

Figure 1. Descriptions of new amphibian species per decade on a global scale until the end of 2003 (including only taxa that are considered to be valid species at present). A steady increase of the numbers is recognizable since 1940. The white bar shows the expectation for the period 2000–2009 if the rate of 2000–2003 continues.

Species discoveries in amphibians

To assess how many newly described amphibian species refer to firsthand discoveries, we have compiled a database of species currently recognized as valid, including their years of description (until the end of 2003), from online and printed primary literature. Of the 1190 species added to the database since 1992, 1020 (85.7 percent) were newly discovered and described; only 170 (14.3 percent) were former subspecies elevated to species rank or revalidations of synonyms. Although we did not exhaustively register new subspecies described in the study period, these were few in number. The number of newly discovered taxa per decade has increased steadily since the 1940s (see also Dubois 2005), and if the current trend continues, up to 1000 new amphibians will be described between 2000 and 2009 (figure 1).

Highly divergent new species

Madagascar is a region that has experienced a particularly steep rise in the numbers of recognized amphibian species, an increase of 42 percent (from 143 to 203) in the period 1992–2003. We here use the endemic Madagascan frog family Mantellidae (Glaw and Vences 2003) as a model group for further exploration of possible taxonomic inflation in amphibians. Very few subspecies have been named for mantellids. Taxonomic inflation in this group should manifest itself by new species being successively less divergent in genetic distance (roughly equivalent to evolutionary history) from already described species. We ordered the 154 currently recognized mantellid species by the year of their taxonomic description and calculated a matrix of pairwise Kimura two-parameter (K2P) sequence divergences in the mitochondrial 16S ribosomal RNA gene from sequences of 140 of these taxa. These distances reflect the proportion of nucleotide differences between two sequences relative to the total number of nucleotides in the DNA fragment studied, after correction for unseen multiple hits, and taking into account differences between transitions and transversions. For each mantellid species, we recorded the divergence from the genetically closest species of an earlier date of taxonomic description. Mean divergence values were summarized for four main research periods in Madagascan herpetology, corresponding to the activity of a limited number of main researchers (1838–1914: Oskar Boettger, George Albert Boulenger, and François Mocquard; 1915–1969: Ernst Ahl, Fernand Angel, and Jean Guibé; 1970–1991: Rose Blommers-Schlösser and Jean Guibé; 1992–2004: Franco Andreone, Frank Glaw, and Miguel Vences). DNA sequences were deposited in GenBank (accession numbers AY847959–AY848683); the original data set used for the calculations is available from M. V. upon request.

The mean (± standard error) pairwise K2P sequence divergences recorded were 0.098 ± 0.006 from 1838 to 1914, 0.077 ± 0.008 from 1915 to 1969, 0.057 ± 0.007 from 1970 to 1991, and 0.071 ± 0.004 from 1992 to 2004 (figure 2). From these values a decrease in genetic divergences after the first period of descriptions was apparent (the differences between the first period and the third and fourth periods, and between the second and third periods, were statistically significant according to U-tests; $P < 0.01$). Such a trend is to be expected, because most of the frogs described in the early exploration of Madagascar belonged to different genera and species groups. However, values increased again in the fourth period (U-test; $P = 0.007$); in this period they were not significantly different from those in the second period. That the recently described species are even more divergent than those of the 1970s and 1980s indicates that exploration is indeed still in its early phase.

It could be hypothesized that newly described species are due to subdivisions of single previously named species. We performed several analyses to test this hypothesis for mantellid frogs. First, we evaluated available data from the comprehensive revision of Blommers-Schlösser and Blanc (1991); from the herpetological catalogs on which their work was largely based, at the Muséum National d'Histoire Naturelle, Paris, and Zoölogisch Museum Amsterdam; and from subsequent species descriptions. For each of the 59 species described after 1991, we assessed whether voucher specimens had already been examined (but not recognized as belonging to a new taxon) by Blommers-Schlösser and Blanc (1991). This is likely for 6 of these species, unlikely for 44 species, and uncertain for 9 species. Second, we estimated which of the 59 species could be clearly diagnosed by morphology or live coloration alone. This was true for 40 species, not true for 10 species, and uncertain for 8 species. Thirty-seven new species were discovered in areas that were previously poorly explored, and 41 were initially recognized as new on the basis of bioacoustic or molecular techniques. Although these evaluations are inevitably in part subjective (original data are available from M. V. upon request), they give a strong indication that most new mantellid species described since 1992 were real new discoveries, not present in major museum collections before; were mainly collected from previously unexplored wregions; and were recognizable through classical morphological methods, although their initial identification was due to nonmorphological techniques.

Altogether, the mantellid frogs described during all four historical periods defined above had high genetic divergence to their closest already named relatives, and the majority of the new species descriptions were not due to subdivision of other, already known species. This suggests that these new species are distinct evolutionary units. We are convinced that this example is representative, and that the distinctness of most amphibian species, especially from species-rich tropical regions, will hold true regardless of the species concept applied. The recent boost in species descriptions probably results from the increased application of bioacoustic and genetic tools (Glaw and Köhler 1998), and especially the intensified exploration of poorly investigated tropical areas. This is confirmed by the spectacular recent discoveries of *Nasikabatrachus syhadrensis,* a representative of a new amphibian family in India (Biju and Bossuyt 2003), and of the first Asian representative of the salamander family Plethodontidae (Min et al. 2005), both of which represent morphologically and genetically highly distinct taxa that had not been collected previously.

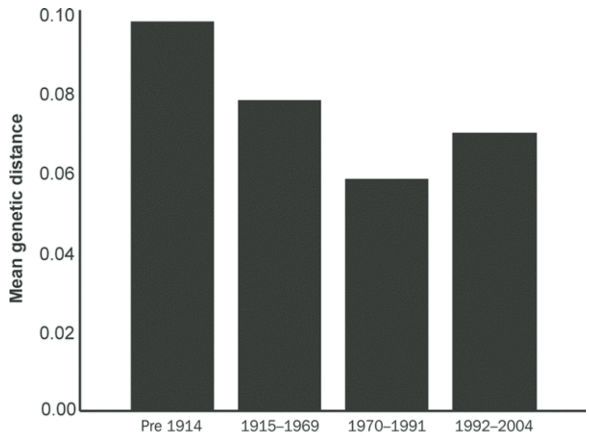

Figure 2. Genetic divergence (Kimura two-parameter distance) in a fragment of the mitochondrial 16S ribosomal RNA gene between newly described mantellid frogs from Madagascar, as compared with their closest already known relative at the time of description. The genetic divergence from other species of mantellids discovered and described in the latest research period (1992–2004) is similar to or greater than that for earlier periods.

Taxonomic inflation: The exception, not the rule

Because of the different species criteria applied, especially among different groups of organisms, species lists do not necessarily reflect comparable categories. The claim of taxonomic inflation may actually hold true for some groups, such as primates and birds, but this may well be the exception rather than the rule. Published studies on mammals and birds are framed less conceptually, and more centered on the particular species under study, than those on ectothermic vertebrates (Bonnet et al. 2002). This could indicate an unconscious bias by editors and referees, favoring taxonomic studies on these organisms. In contrast, many "unpopular" taxonomic groups suffer from an underestimation of their species richness because of the small number of taxonomists dealing with them (Butler et al. 1998).

The application of modern methodology reveals that in many cases several cryptic species may hide under a single taxon name. If this is true of amphibians, even the high number of threatened amphibian species provided by Stuart and colleagues (2004) probably represents an underestimation of the actual threats to this vertebrate group. The recognition of new species may exacerbate an organism's threat status, because it can result in subdivision of a once widespread species into numerous species, each with a smaller and, hence, a more precarious distribution. For amphibians, this might be true in Sri Lanka, where the actual number of amphibian species is likely to be more than double the number that is currently recognized (Meegaskumbura et al. 2002, Dubois 2005), and where many of the yet-undescribed rhacophorid frogs are local endemic species. Cryptic species may also have different demands on their ecological environment and thus require different conservation measures, and incomplete taxonomic knowledge may lead to omission of true biodiversity hotspots. In general terms, taxonomic progress will foster rather than confuse the identification of species-rich areas and conservation needs. Taxonomic exploration is urgently needed, more than ever before, to avoid misinterpretations in global conservation policy.

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