Review

Conservation Biology of Caecilian Amphibians

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Abstract: *Most of the available data on declining populations of amphibians pertain to frogs and, to a lesser extent, salamanders. In keeping with their generally less understood biology, the population trends and conservation status of caecilian amphibians (Gymnophiona) are also much less known. We reviewed reports of threats to and declines of populations of caecilians. Despite a lack of field-study details (e.g., localities, dates, and sampling methods) and quantitative data, there are several recent reports of threats to and declines and extinctions of caecilians. A range of causal explanations (habitat loss, pollution, chytridiomycosis, and scientific collecting) for these perceived declines have been proposed but little or no associated evidence has been given. Although caecilians are often considered rare and thought to require pristine habitat, published, quantitative data demonstrate that at least some species can occur in high abundance in disturbed, synanthropic environments. Few estimates of caecilian population parameters have been made and very few field methods have been tested, so the assumed rarity of any taxa remains inadequately demonstrated. Distribution and taxonomic data are also inadequate. Because they are generally poorly known and often cryptic, caecilians can be overlooked in standard faunal surveys, meaning that lack of opportunistic collection over several years might not represent evidence of decline. The conservation status of most species must be considered data deficient. More precise assessments will require a substantial increase in all areas of caecilian research, especially those involving new fieldwork. Future reports of caecilian conservation biology need to be explicit and more quantitative.*

Key Words: Amphibia, ecology, Global Amphibian Assessment, Gymnophiona, population declines, taxonomy

Conservación de Anfibios Cecilianos

Resumen: *La mayoría de los datos disponibles sobre poblaciones de anfibios en declinación se refieren a ranas y en menor grado, a salamandras. En el marco del poco conocimiento de su biología, las tendencias poblacionales y el estatus de conservación de anfibios cecilianos (Gymnophiona) son mucho menos conocidos. Revisamos los reportes de amenazas a y declinaciones de poblaciones de cecilianos. A pesar de la falta de detalles de los estudios de campo (e.g., localidades, fechas y métodos de muestreo) y de datos cuantitativos, hay varios reportes recientes de amenazas a y declinaciones y extinciones de cecilianos. Se han propuesto varias explicaciones de las causas (pérdida de hábitat, contaminación, chitridiomicosis, colecta científica) de estas declinaciones, pero con poca o ninguna evidencia asociada. Aunque los cecilianos a menudo son considerados raros y que requieren hábitat prístino, hay datos, cuantitativos, publicados que demuestran que por lo menos algunas especies pueden ocurrir en abundancia elevada en ambientes sinantrópicos perturbados. Se han hecho escasas estimaciones de parámetros poblacionales de cecilianos y se han probado muy pocos métodos de campo, así que la rareza asumida de cualquier taxón permanece inadecuadamente demostrada. Los datos taxonómicos y de distribución también son inadecuados. Siendo generalmente poco conocidos y a menudo crípticos, los cecilianos pueden ser pasados por alto en muestreos estándar de fauna, así que la falta de recolectas oportunistas a lo largo de varios años puede no representar evidencia de declinación. El estatus de conservación de la mayoría de especies debe ser considerado como deficiente en datos. Evaluaciones más precisas requerirán de un incremento considerable en todos los campos de investigación sobre cecilianos,*

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especialmente los que implican nuevo trabajo de campo. Los futuros reportes sobre biología de la conservación de cecilianos necesitan ser explícitos y más cuantitativos.

Palabras Clave: Amphibia, declinaciones poblacionales, ecología, Evaluación Global de Anfibios, Gymnophiona, taxonomía

Introduction

There has been much recent concern about global amphibian population declines. Although known for frogs and salamanders, unequivocal declines have not been documented for caecilians (e.g., Houlahan et al. 2000; Young et al. 2001), and the group is barely mentioned in a recent volume on amphibian conservation (Semlitsch 2003). Caecilians exhibit a diversity of reproductive modes (oviparity with aquatic larvae, oviparity with direct development, and at least two modes of viviparity; Loader et al. 2003) and habits (probably fully subterranean to occasionally surface cryptic and semiaquatic to aquatic), and live in a variety of habitats (evergreen rainforest to highly seasonal deciduous forest and open terrain). This diversity exposes different species and life-history stages to potentially detrimental environmental variables (e.g., water and soil pollutants and ultraviolet-B radiation) to varying degrees and in ways that might make caecilians useful for comparative testing of hypothesized causes of amphibian declines.

Relatively little is known about the approximately 160 nominate species (Nussbaum & Wilkinson 1989) of caecilians (order Gymnophiona). The group occurs across much of the wet tropics and some subtropical regions except Madagascar, Australasia, and Southeast Asia east of Wallace's line (e.g., Taylor 1968). Their distribution coincides with several of the world's major biodiversity hotspots (see Appendix). Of the six currently recognized families (e.g., Nussbaum & Wilkinson 1989), the South American Typhlonectidae includes aquatic and subaquatic forms, but, where known, members of other families spend most of their adult lives burrowing in soil or leaf litter. Because of their largely tropical distribution and subterranean habits, they are rarely encountered in routine herpetological surveys. This perhaps partly explains the lack of detailed assessments of caecilian population trends; most published amphibian data are from surface-dwelling species in North America, Europe, and Australia (e.g., Green 2003). Caecilian taxonomy is unstable (e.g., Nussbaum & Wilkinson 1989) probably because it has been based on a very incomplete understanding of variation and has relied on few characters and sparse samples. Several species are known only from a single specimen and many more from very small series (e.g., Taylor 1968; Giri et al. 2003).

We reviewed reports of caecilian species under threat or in decline, causal explanations for perceived declines, and evidence presented to support these claims. Here we summarize our findings and discuss current knowledge and issues that should be considered in future work. This is the first review of the conservation status and possible population declines for this order of vertebrates.

Declining Caecilian Populations

Early concern was voiced for the caecilians of the generally threatened biodiversity hotspot of the Western Ghats (Gundappa et al. 1981), but declines were not reported for specific taxa. All Western Ghats caecilians (e.g., Daniels 2002: 38), except perhaps a few species of *Ichthyophis* (Ghate 2002: 99; Padhye & Ghate 2002: 736), are considered to be declining because some historic localities have not yielded any recent specimens (Pillai & Ravichandran 1999: 94; Ghate 2002). At the 1997 Conservation Assessment and Management Plan (CAMP) workshop (Molur & Walker 1998) all considered caecilians from India were categorized as threatened to some degree, with 11 vulnerable, 4 endangered, and 1 (*Indotyphlus battersbyi*) critically endangered. National-level assessments in Sri Lanka in 1993 and 1999 list all three currently recognized species (the endemic *Ichthyophis glutinosus, I. orthoplicatus,* and *I. pseudangularis*) as threatened (World Conservation Union [IUCN] 2000).

In Southeast Asia, Chinese populations of *Ichthyophis bannanicus* are reported to have declined sharply (Wen 1998) to the extent that "establishing a nature reserve for its protection is urgently necessary" (Zhao 1998: 3). The IUCN's official lists of threatened species include only two species of caecilians. In 1999 the Philippine ichthyophiids *Ichthyophis glandulosus* and *I. mindanaoensis* were categorized as endangered and vulnerable, respectively (World Conservation Union 2003). The ichthyophiid(s) of Singapore, of unclear taxonomic identity, are considered endangered (Lim 1994).

Few investigators have explicitly considered the conservation status of African caecilians. In the vicinity of Kenya where the type series of *Boulengerula taitanus* was collected (Loveridge 1937), reported deforestation has caused concern for the survival of this species (Glaser 1984).

In the New World, concern has been expressed about the Central American *Dermophis oaxacae*—a species known from approximately 30 specimens collected before 1973—and monitoring and maintenance programs are considered necessary for any remaining populations

(Wake 1998: 2). The Bolivian *Caecilia marcusi* was thought to be extinct (Wake 1993: 115), but subsequent work showed that it is extant, at least in forests (Reichle & Köhler 1996; De la Riva et al. 2000). In Central America, changing land use is reported to have altered distribution patterns and led to population and species extinction, and new field studies are urged (Wake et al. 2004). Uruguay's only recorded caecilian, the typhlonectid *Chthonerpeton indistinctum,* is thought to have declined or to be extinct in at least one of its historical localities, Arroyo Carrasco (Maneyro & Langone 2001).

Caecilians in general are reported to be declining and facing extinctions (Pennisi 2000: 623; Wake 2002: 41; Wake 2003: 1810). However, no quantitative data are given in most reports, and causal hypotheses have not been tested.

Causes of Decline

Habitat Change

The primary cause of perceived caecilian declines is thought to be habitat destruction, chiefly through deforestation and pollution. Habitat destruction is considered a major threat in India (Gundappa et al. 1981: 480; Pillai & Ravichandran 1999: 84; Daniels 2002), Southeast Asia (Lim 1994; Wen 1998; Zhao 1998; World Conservation Union 2003), Africa (Glaser 1984), and the Neotropics (Wake 1993). For example, the presumed natural habitat of the Philippine *Ichthyophis glandulosus* and *I. mindanaoensis* "has almost all been cleared and the forest streams, critical for larval development, are polluted and drying up" (World Conservation Union 2003). Urbanization is reported to have caused the decline and possible local extinction of *Chthonerpeton indistinctum* in Uruguay (Maneyro & Langone 2001), and the urbanization of historical localities for *Ichthyophis supachaii* in southern Thailand is also reported (Kupfer & Müller 2004). Agriculture is cited as the proximate cause of caecilian habitat destruction in many places (Wake 1993, 1994, 2002; Wen 1998; Zhao 1998; Pillai & Ravichandran 1999: 84). For example, the type locality of the (once thought to be extinct) *Caecilia marcusi* is in an area of Bolivia "converted to many square kilometres of cocaine poppy fields" (Wake 1993: 115).

In this century, change in land use is predicted to have potentially the largest effect on global terrestrial ecosystems, especially for tropical ecosystems and subterranean organisms (Sala et al. 2000), which means that caecilians might be particularly threatened. Knowledge of their habitat requirements and preferences is important in assessing threats, but little is actually known. It is generally assumed that most terrestrial caecilians are primarily inhabitants of moist forests (e.g., Gundappa et al. 1981; Wake 1994). Some terrestrial caecilians, however, are also known from open terrain and deciduous and strongly seasonal scrub and woodland that might at least partly represent native habitats of some species (e.g., *Indotyphlus battersbyi*, *Chthonerpeton indistinctum*, and *Schistometopum gregorii*; D.J.G. & M.W., personal observations). In general, replacement of primary habitat by agriculture or other anthropogenic ecosystems might be expected to be detrimental to many taxa, but there is evidence that the situation is more complex.

Anthropogenic habitat changes often do not have a negative impact on all taxa. "Certain kinds of habitat disturbance are not detrimental to caecilians and may even provide good conditions for them" (Wake 1993: 115). From published reports (e.g., Nussbaum & Pfrender 1998; Hofer 2000) and our own field experience, we know that this can be the case for several terrestrial species, at least where forest is replaced with crops that maintain shade and moisture and restrict soil erosion. Glaser (1984) believes that reports of high abundance of the East African *B. taitanus* and *Schistometopum gregorii* in agricultural habitats provide some hope for caecilian conservation. Indeed, the highest densities ever reported for caecilians are for the caeciliid *Gegeneophis ramaswamii* in plantations (some monoculture) in the Western Ghats of India (Oommen et al. 2000; Measey et al. 2003*b*). There are almost no published data on comparative abundance in primary and in synanthropic habitats for any caecilian (but see Measey 2004). In a study in the Western Ghats, more caecilians were found killed on roads passing through agricultural land than on those passing through forest (Vijayakumar et al. 2001: 257), although comparative data on traffic levels are not presented.

It is possible that irrigation increases the area of suitable habitat for *B. taitanus* in Kenya so that this species "seems to thrive when the forest is removed" (Hebrard et al. 1992: 514). Other researchers suggest that agriculture may not be detrimental for some caecilian species, especially if it is sympathetic and not too intensive (Oommen et al. 2000). Local agricultural workers and rural people in some parts of São Tomé (Hofer 2000), Sri Lanka, and India (D.J.G. & M.W., personal observations), for example, believe that some caecilian populations have declined following the increased use of agrochemicals, which also may have affected *B. taitanus* in Kenya (Hebrard et al. 1992). Oommen et al. reported in 2000 that they did not find caecilians in Indian plantations where agrochemicals were being used. More recently, however, (2002; O.V. Oommen, personal communication) *G. ramaswamii* and *Uraeotyphlus* cf. *naryani* have been found in some of their study sites, so the use of agrochemicals does not necessarily preclude caecilian survival.

Diversity can remain high in agricultural settings for other tropical herpetofauna (e.g., Andreone et al. 2003). The situation for terrestrial caecilians is unlikely to be uniform because caecilians are ecologically diverse (e.g., Gower et al. 2004*a*) and because changes in tropical soil quality that occur when native habitats are replaced with agriculture vary widely depending on the types of soil and farming (Stocking 2003). At least one aquatic caecilian, *Typhlonectes natans*, thrives in some eutrophic waters in synanthropic and urbanized habitats in Venezuela, among human habitation and associated waste that includes oil pollution (M.W., personal observation). Similarly, it is reported that some caecilians occur in places where human waste is dumped, and that *Typhlonectes* are "abundant" and "widespread" in some synanthropic habitats in Colombia and Guyana (Hofer 2000).

There are few, largely inconclusive data available on environmental variables in caecilian habitats. For example, it has been suggested that acidic soil is a prerequisite for terrestrial caecilians (Gundappa et al. 1981: 483). Several Indian species, however, occur in soils that are not acidic (Oommen et al. 2000), and it is reported that captive "caecilians do not do well in very acidic soil" (Wake 1994: 224). One species of *Ichthyophis* lives in naturally acidic conditions (about pH 4; Kupfer 2002) but thrives in captivity at a neutral pH (Kramer et al. 2001). Clearly, more data are required and a distinction must be made between conditions recorded in habitats yielding caecilians and those that are preferred or tolerated.

We probably know much more about caecilians that survive or thrive in disturbed habitats and little to nothing about species that may have greatly declined or possibly become extinct through the creation of such habitats. Unfortunately, there are currently insufficient historical or contemporary data to adequately assess potential declines following habitat alteration. A better understanding of current caecilian faunas and populations in pristine and nearby disturbed habitats will allow this issue to be explored more satisfactorily.

Habitat destruction plays a primary role in declining populations of other amphibians, but other biotic and abiotic factors are also important (e.g., Gardner 2001; Blaustein & Kiesecker 2002; Blaustein et al. 2003; Collins & Storfer 2003; Daszak et al. 2003), including climate change (Thomas et al. 2004). It has not been proposed that perceived caecilian declines are caused by climate change, but other threats have been suggested.

Disease

Chytridiomycosis is a factor in the decline of frogs and salamanders (e.g., Berger et al. 1998; Daszak et al. 1999, 2003). We are aware of only a single report of chytrid fungus (and no reports of any other infections) killing wild caecilians (Wake 2002: 41). It is now clear that this report was based on a mistaken understanding—there have been no studies of chytridiomycosis in caecilians and there are no confirmed reports (M. H. Wake, K.R. Lips, personal communications 2003).

Scientific Collecting

In their discussion of Indian caecilians, Pillai and Ravichandran (1999: 94) report that "As a queer 'snake-like frog,' caecilians are in great demand as exhibits for college museums, . . . specimen suppliers have mercilessly depleted them, [t]hey have . . . been exterminated in large numbers . . . for biochemical analysis and tissue-assay studies, [and]. . . extensive area[s] . . . have been dug up [and] caecilians . . . collected in hundreds." The only Indian laboratory we know of that regularly collected caecilians for biochemical research is at the Department of Zoology of the University of Kerala. Work on collections made over about a decade beginning in the late 1980s (O.V. Oommen, personal communication) produced several publications on caecilian endocrinology (e.g., Josekumar & Oommen 1988; Subash Peter et al. 1996). Virtually all the specimens collected for these studies were of *Gegeneophis ramaswamii* (not *G. carnosus*, as stated in these publications) from agricultural habitats at a single locality, the tea estate at Bonaccord. Recent surveys that found *G. ramaswamii* in high abundance in this locality (Oommen et al. 2000; Measey et al. 2003*b*) show that these extensive collections over many years did not detrimentally affect the local population.

Further evidence that even long-term scientific collecting may not threaten caecilian populations is provided by many years of research (1981 to present) on a single population of *Ichthyophis* sp. in northeastern Thailand (e.g., Himstedt 1996 and references therein; Kramer et al. 2001; Kupfer et al. 2004*a*, 2004*b*). Specimens have been collected there from a small area of an agricultural landscape, sometimes in several successive years, without any indication that the resident population has decreased (W. Himstedt & A. Kupfer, personal communication).

Terrestrial caecilians are sometimes killed during the digging of soil in agricultural land (Measey et al. 2001, 2003*a*, 2003*b*), and many are killed by farmers mistaking them for snakes. Such mortality must greatly dwarf the mortality caused by even the biggest scientific collection efforts from agricultural habitats. In a study in peninsular India, 19 *Uraeotyphlus* sp. and 8 *Ichthyophis* sp. were found dead on roads (total of 170.7 km of road distance) sampled over 6 weeks (Vijayakumar et al. 2001). This number of *Uraeotyphlus* exceeds the individual holdings of most or all of the world's major museum collections, and it further suggests that scientific collection is responsible for less caecilian mortality than everyday human action in areas where humans and caecilians coexist. The presence of caecilians in the soil is not generally betrayed by surface indications, so targeted scientific collecting of terrestrial caecilians usually involves extensive digging. Digging is a rate-limiting step for collecting terrestrial caecilians and, in our experience, small teams of researchers are extremely limited in the areas that they can thoroughly search. Massive harvesting of an already threatened species across the whole range of a small distribution would be detrimental (and reckless), but the necessary effort (and recklessness) makes it extremely unlikely that this would happen.

Despite expressing concern about levels of scientific collecting, some researchers also recognize that for Indian caecilians "[s]pecimens available in museums of the world are far too few to establish the validity of existing species," and that "[f]urther explorations and intensive surveys are needed to document their distribution" (Pillai & Ravichandran 1999: 93). We fully endorse this perspective. The listing of species on threatened lists should not automatically be used as a means to limit scientific collecting (see also Molur & Walker 1998: 176). It may be particularly important to make scientific collections of threatened species when studies are needed to further understand their biology and conservation. There are extremely few examples of plant and animal species threatened by scientific collecting and no evidence of its causing caecilian declines. The IUCN generally views scientific collecting as an aid to conservation, not a threat (S. Stuart, personal communication). We applaud this perspective, and add that associated, accurate, and precise collection data and good preservation and storage in an accessible repository maximize the value of any scientific collection, not least for conservation biology. We do not consider scientific collecting a current threat for any caecilian species.

Pet Trade

Caecilians are uncommon pets, but there is occasional trade in animals collected from the wild. The aquatic South American typhlonectid *T. natans* has been traded for at least 20 years (Wilkinson 1981) and is the commonest species available on the market—at least in Europe and North America—perhaps as a bycatch of tropical fish collecting (e.g., Wake 1994). Observation of abundant aquatic caecilians in synanthropic habitats in South America has been used to argue that the export of *Typhlonectes* spp. for the pet trade does not need to be restricted (Hofer 2000). Terrestrial species that are also occasionally available commercially include *Ichthyophis* spp., probably from Southeast Asia; species of *Boulengerula* and *Scolecomorphus* from East Africa; *Herpele squalostoma* and *Geotrypetes* cf. *seraphini* from Cameroon and perhaps neighboring countries; and *Dermophis mexicanus* from Central America. At least some of these taxa appear to occur at least sometimes in high abundance (D.J.G. & M.W., personal observation; Hofer 2000; Gower et al. 2004*a,* 2004*b*), but quantitative estimates of population sizes have not been reported. Additionally, there appear to be limited ways to fully assess the threat that the pet trade may pose, especially without accurate and precise locality data. Most caecilians have not been bred in captivity, although success has been reported for the aquatic *Typhlonectes* (e.g., Körber 1987), semiaquatic *Chthonerpeton indistinctum* (Barrio 1969), and terrestrial *S. thomense* (Haft & Franzen 1996; O'Reilly 1996) and *Ichthyophis* spp. (Kramer et al. 2001).

Threatened Species Lists

Data sheets from the 1997 CAMP assessments (see Molur & Walker 1998) report "continuing decline observed in area of occupancy" for all 16 species of Indian caecilian, but numbers are given for only *Ichthyophis beddomei* and *I. longicephalus* (declined by 20% and <20%, respectively, over 10 years). It is unclear, though, how decline was assessed or quantified. For example, one of the species recorded as declining (*G. fulleri*) is known from only a single specimen collected before 1905 (e.g., Pillai & Ravichandran 1999), and decline of *Ichthyophis longicephalus* was quantified despite the fact that the assessment was "based only on 3 specimens." The lack of explicit data has resulted in several changes to the conservation status of caecilians in the recent Global Amphibian Assessment (Appendix).

For amphibians of the Western Ghats, there are "hardly any quantitative data with respect to population size, reproductive potential, survivorship. . ." so concrete statements on conservation status are generally not possible (Ghate 2002: 98; Padhye & Ghate 2002: 736). The categorization of the conservation status of Uruguayan *Chthonerpeton indistinctum* as "atención especial," the most fragile of three categories, is based on scores given for distribution, habitat use, abundance, and reproductive potential, but sources of data are not given. The IUCN listing of *Ichthyophis glandulosus* and *I. mindanaoensis* was based on the consideration by a panel in 1999 of perceived threats, known distributions, and panel members' field experience (A. Diesmos & C. Banks, personal communication). The same approach was used frequently for caecilians in the recent Global Amphibian Assessment (Appendix).

We believe that the conservation status of the majority of caecilian species must be considered data deficient (Appendix). According to the World Conservation Union (2003) "great care should be exercised in choosing between DD [data-deficient] and threatened status. If the range of a taxon is suspected to be relatively circumscribed, if a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified." The point about time elapsed since the last record is particularly important. A long absence of records for conspicuous species should provoke concern about conservation status, but the same might not be the case for an inconspicuous, difficult to identify, almost permanently soil-dwelling amphibian, especially where routine faunistic surveys do not include digging (e.g., Gower et al. 2004*b*).

Threatened species lists might have limited value in certain respects because of "uneven taxonomic treatment; variation in observational effort; and the fact that changes in the lists more often reflect change in knowledge of status rather than change in status itself" (Possingham et al. 2002: 505). Caecilians might be expected to be particularly affected by such biases (Nussbaum & Wilkinson 1989), but this might be less of a problem if lists are linked to supplementary information detailing the data used in assessments. Such a modification might be one of the improvements (see also Lamoreux et al. 2003) that would continue to make the IUCN Red List a useful, central framework for conservation biology.

Population Assessment

"Caecilians are difficult to sample because they are aquatic or fossorial and are rarely observed," and "[t]here are no widely known techniques for sampling caecilians" (Heyer et al. 1994: 7; Pillai & Ravichandran 1999: 4, 93). Soil-dwelling vertebrates can be overlooked in routine (without digging) surveys of terrestrial faunas (Gower et al. 2004*b*). For example, workers in one study involving more than 6000 person-hours of above-soil quadrat, transect, and visual encounter surveys in Peruvian rainforest (Doan 2003) found only one caecilian, a *Caecilia* sp., and it was under attack from ants (T.M. Doan, personal communication). In contrast, 85 *B. boulengeri* were found in 76 person-hours of digging in a Tanzanian rainforest, but no specimens were encountered in associated pitfall trapping or casual visual surveys (Gower et al. 2004*a*). In their handbook on monitoring Neotropical amphibians, Lips et al. (2001: 9) state, "It is not possible to monitor all species of amphibians because many (especially tropical salamanders and caecilians) are secretive and are encountered in such low numbers that population trend estimates are impossible." Similar views are expressed elsewhere (e.g., Doan 2003: 74). Although possibly true for some species, several reports of high abundance of caecilians, including Neotropical species (Sarasin & Sarasin, 1887–1890; Loveridge 1936; Seshachar 1942; Largen et al. 1972; Glaser 1984; Hebrard et al. 1992; Nussbaum & Pfrender 1998; Hofer 2000; Oommen et al. 2000; Measey & Di-Bernardo 2003; Measey et al. 2003*a*, 2003*b*) justify greater optimism that meaningful quantitative ecological study is possible for at least some caecilians.

Reports of a lack of recent collection of specimens (e.g., Wake 1993, 1998; Pillai & Ravichandran 1999; Ghate 2002; Padhye & Ghate 2002) generally do not detail the unsuccessful effort. Studies reporting differential collections of some versus zero specimens over time (e.g., Pillai & Ravichandran 1999) do not include specific sampling regimes or data amenable to statistical analysis. Others (e.g., Wen 1998) assert that populations are declining but present no explicit methods or data. The duration of resurveys and the type of data gathered affect what can be determined about distribution change and decline (Skelly et al. 2003), making the lack of details about reported negative sampling in known caecilian localities doubly frustrating. In some cases, the lack of clear evidence has already been recognized (e.g., Crump 2003: 55; AmphibiaWeb 2004: entry for *Ichthyophis bannanicus*). The "probability of extinction should be correlated both with population size variance and with the extent of population isolation" (Green 2003: 331). These parameters are simply unknown for caecilians. There are virtually no data on population size in any species anywhere (Measey et al. 2003*a*, 2003*b*), so it is not surprising that evidence to support claims of decline in the form of long-term quantitative data is entirely lacking.

If "there is a desperate need for comprehensive monitoring studies on amphibian populations world-wide" (Gardner 2001: 35), perhaps caecilians should be included. Populations of other amphibians can fluctuate dramatically (e.g., Semlitsch et al. 1996) even in the absence of anthropogenic factors, and long-term study is required to accurately estimate population size without undue influence of stochastic factors (Meyer et al. 1998; Marsh 2001). No long-term studies have been carried out on any caecilians. Recently, some progress has been made toward trials of field methods for assessing caecilian abundance. Tested methods include marking techniques (Measey et al. 2001), mark-recapture studies (Measey & Di-Bernardo 2003; Measey et al. 2003*a*), and quantitative, randomized surveys (Kupfer 2002; Measey et al. 2003*b*; Measey 2004). More work is urgently required to test the efficacy and to extend, refine, and standardize appropriate field methods, but those already available can be used now to obtain sorely needed baseline data. Long-term quantitative studies may prove unfeasible for some species, situations, or both, but this must not be assumed a priori.

Distribution Change

The lack of discovery of caecilians at a site where they had previously been recorded need not be explained only as decline (or sampling failure); it could also be considered a change in distribution. In addition to lack of published details on negative caecilian sampling mentioned previously and the need to consider resampling duration (Skelly et al. 2003), the baseline distribution data for almost all caecilian species are poor. As with other amphibians, caecilian species may be structured as metapopulations, some of which may suffer background extinction or decline without the species as a whole being threatened. Thus, accurate knowledge of distribution is an important factor in assessing conservation status. Currently, even small-scale surveys can substantially expand the known distribution of some supposedly uncommon caecilian species (e.g., Oommen et al. 2000). Many more field data are needed.

Taxonomy

Conservation biology demands good taxonomy (e.g., Daugherty et al. 1990; Molur & Walker 1998; Keogh et al. 2001; Dubois 2003; Valdecasas & Camacho 2003). For many caecilian genera, the most recent taxonomic treatments and keys available are those of Taylor (1968). Many parts of Taylor's (1968) work include inconsistencies and errors (e.g., Wilkinson 1988; Wilkinson & Nussbaum 1992; Kupfer & Müller 2004), and these seriously compromise the ability of biologists to use published keys and descriptions to identify caecilians. Inadequate taxonomy is one of the main factors leading to a data-deficient status of caecilian species in the recent Global Amphibian Assessment (see Appendix). We caution against uncritical use of the taxonomic literature and recommend the collection and deposition of voucher specimens of any caecilians encountered in ecological, biogeographic, or conservation field studies.

Summary and Prospectus

Many publications claiming to address the conservation of Amphibia communicate little or nothing about caecilians. Workers trying to synthesize and manage databases on amphibian populations worldwide have noted a general lack of data, and a specific plea has been made for population information on caecilians (and salamanders) so that knowledge of possible amphibian declines becomes more than information on frog declines (Halliday 1999). Anecdotal concerns merit consideration but, to be useful, reports should include details of taxa, dates, and localities. Future reports of caecilian population trends need to be of higher scientific quality. Inadequate taxonomy is a serious impediment to all branches of caecilian research. Taxonomic instability and difficulties in identification dictate that for most species voucher specimens need to be collected for all forms of study. The need for taxonomic revision is exemplified by the currently inadequate knowledge of most of the species of the two largest genera, the Neotropical *Caecilia* and Asian *Ichthyophis*, but all caecilian species require further taxonomic study.

In some ways the current level of knowledge of potential caecilian population declines is reminiscent of the situation with frogs a decade ago (see, for example, Blaustein 1994; McCoy 1994; Pechmann & Wilbur 1994; Travis 1994). Some claims of caecilian declines and causes of declines have been made but without clear evidence and few suggestions about how to progress. The current situation for caecilians, however, is undoubtedly worse. The relatively great knowledge and interest in frogs allows possible declines to come to attention fairly swiftly and engenders better understanding of how to tackle scientific questions that are raised. In the face of known declines of some noncaecilian amphibians, the absence of data is not a firm basis for being indifferent to claims of caecilian declines. One simple response is to call for immediate monitoring programs to be established, but this requires additional consideration of, for example, how monitoring should be undertaken and which species and habitats should be investigated. To begin to address these questions, more fundamental research in caecilian biology is needed. In particular, field-based research will improve the meager knowledge of caecilian biology and dramatically increase the chances of identifying instances of possible decline that merit dedicated study.

The potential threat of chytridiomycosis merits immediate assessment, especially in highland Central and South America and Tanzania (areas of caecilian distribution in which this disease is known to have killed populations of other amphibians; see, for example, Daszak et al. 2003; Weldon & du Preez 2004). Chytrid fungi inhabit water and moist soil (e.g., Daszak et al. 1999), so caecilians might be particularly exposed. Aquatic caecilians or those with an aquatic larval stage might be targeted for initial investigations, although all Central American and Tanzanian species (where known) are terrestrial and have direct development or are viviparous.

Caecilian species that have not been reported for many years, often since their initial description, should be a priority for precise and accurate revisions of conservation-status data. Outstanding examples include the West African *Crotaphatrema bornmuelleri* (not reported since 1893) and *Herpele multiplicata* (1912 or earlier), East African *B. denhardti* (1912 or earlier), and Indian *G. fulleri* (1904 or earlier)—the latter three are each known from single specimens.

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Literature Cited

AmphibiaWeb. 2004. Information on amphibian biology and conservation. AmphibiaWeb, Berkeley, California. Available from http://amphibiaweb.org/ (accessed March 2004).

Andreone, F., F. Glaw, R. A. Nussbaum, C. J. Raxworthy, M. Vences, and J. E. Randrianirina. 2003. The amphibians and reptiles of Nosy Be (NW Madagascar) and nearby islands: a case study of diversity and conservation of an insular fauna. Journal of Natural History **37**:2119–2149.

Barrio, A. 1969. Observaciones sobre *Chthonerpeton indistinctum* (Gymnophiona, Caecilidae) y su reproduccion. Physis **28:**499–503 (in Spanish).

Berger, L. et al. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Sciences of the United States of America **95:**9031–9036.

Blaustein, A. R. 1994. Chicken little or Nero's fiddle? A perspective on declining amphibian populations. Herpetologia **50:**85–97.

Blaustein, A. R., and J. M. Kiesecker. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. Ecology Letters **5:**597–608.

Blaustein, A. R., J. M. Romansic, J. M. Kiesecker, and A. C. Hatch. 2003. Ultraviolet radiation, toxic chemicals and amphibian population declines. Diversity and Distributions **9:**123–140.

Collins, J. P., and A. Storfer. 2003 Global amphibian declines: sorting the hypotheses. Diversity and Distributions **9:**89–98.

Crump, M. L. 2003. Conservation of amphibians in the New World Tropics. Pages 53–69 in R. D. Semlitsch, editor. Amphibian conservation. Smithsonian Books, Washington, D.C.

Daniels, R. J. R. 2002. Some aspects of the threatened amphibians of India. Pages 35–39 in B. D. Sharma and T. Kumari, editors. Indian wildlife. Threats and preservation. Anmol Publications, New Delhi.

Daugherty, C. H., A. Cree, J. M. Hay, and M. B. Thompson. 1990. Neglected taxonomy and continuing extinctions of tuatara (*Sphenodon*). Nature **347:**177–179.

Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases **5:**735–748.

Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2003. Infectious diseases and amphibian population declines. Diversity and Distributions **9:**141–150.

De la Riva, I., J. Köhler, S. Lötters, and S. Reichle. 2000. Ten years of research on Bolivian amphibians: updated checklist, distribution, taxonomic problems, literature and iconography. Revista Española de Herpetolgía **14:**19–164.

Doan, T. M. 2003. Which methods are most effective for surveying rain forest herpetofauna? Journal of Herpetology **37:**72–81.

Dubois, A. 2003. The relationships between taxonomy and conservation biology in the century of extinctions. Comptes Rendus Biologies **326:**S9–S21.

Gardner, T. 2001. Declining amphibian populations: a global phenomenon in conservation biology. Animal Biodiversity and Conservation **24:**25–44.

Ghate, H. V. 2002. Amphibian fauna. Pages 97–100 in A. P. Jagtap and N. P. Singh, editors. Biodiversity of the Western Ghats of Maharashtra—current knowledge. Bishen Singh Mahendra Pal Singh, Dehra Dun, India.

Giri, V., D. J. Gower, and M. Wilkinson. 2003. A new species of *Gegeneophis* Peters (Amphibia: Gymnophiona: Caeciliidae) from the Western Ghats of southern Maharashtra, India, with a key to the species of the genus. Zootaxa **351:**1–10.

Glaser, H. S. R. 1984. Observations on an abundant caecilian, *Afrocaecilia taitana*, in Kenya. ASRA Journal **2:**47.

Gower, D. J., S. P. Loader, C. B. Moncrieff, and M. Wilkinson. 2004*a*. Niche separation and comparative abundance of *Boulengerula boulengeri* and *Scolecomorphus vittatus* (Amphibia: Gymnophiona) in an East Usambara forest, Tanzania. African Journal of Herpetology **53:**183–190.

Gower, D. J., S. P. Loader, and M. Wilkinson. 2004*b*. Assessing the conservation status of soil-dwelling vertebrates: insights from *Typhlops uluguruensis* (Reptilia: Serpentes: Typhlopidae). Systematics and Biodiversity **2:**79–82.

Green, D. M. 2003. The ecology of extinction: population fluctuation and decline in amphibians. Biological Conservation **111:**331–343.

Gundappa, K. R., T. A. Balakrishna, and K. Shakuntala. 1981. Ecology of *Ichthyophis glutinosus* (Linn.) (Apoda, Amphibia). Current Science **50:**480–483.

Haft, J., and M. Franzen. 1996. Freilandbeobachtungen, Verhalten und Nachzucht der Sao Tome-Blindwuhle *Schistometopum thomense* (Bocage, 1873). Herpetofauna **18:**5–11 (in German).

Halliday, T. 1999. Call for information on urodeles and caecilians. Froglog **35:**2.

Hebrard, J. J., G. M. O. Maloiy, and D. M. I. Alliangana. 1992. Notes on the habitat and diet of *Afrocaecilia taitana* (Amphibia: Gymnophiona). Journal of Herpetology **26:**513–515.

Heyer, W. R., M. A. Donelley, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institution Press, Washington, D.C.

Himstedt, W. 1996. Die Blindwühlen. Westarp Wissenschaften, Magdeburg, Germany (in German).

Hofer, D. 2000. A short note about the status and abundance of caecilian populations. Froglog **42:**1.

Houlahan, J. E., C. S. Findlay, B. R. Schmidt, A. H. Mayer, and S. L. Kuzmin. 2000. Quantitative evidence for global amphibian declines. Nature **404:**752–755.

Josekumar, V. S., and O. V. Oommen. 1988. Effect of adrenaline on hepatic enzyme activities in an apodan amphibian *Gegeneophis carnosus*. Indian Journal of Experimental Biology **26:**796–800.

Keogh, J. S., D. G. Barker, and R. Shine. 2001. Heavily exploited but poorly known: systematics and biogeography of commercially harvested pythons (*Python curtus* group) in Southeast Asia. Biological Journal of the Linnean Society **73:**113–129.

Körber, U. 1987. Nachzucht der Schwimmwühle *Typhlonectes compressicaudus*. Die Aquarien- und Terrarien-Zeitschrift **40:**368–370 (in German).

Kramer, A., A. Kupfer, and W. Himstedt. 2001. Haltung und Zucht der thailändischen Blindwühle *Ichthyophis kohtaoensis* (Amphibia: Gymnophiona: Ichthyophiidae). Salamandra **37:**1–10 (in German).

Kupfer, A. 2002. Lebensgeschichte und Ökologie der Blindwühle *Ichthyophis kohtaoensis* (Amphibia: Gymnophiona) in einer Kulturlandschaft im Nordosten Thailands. Ph.D. thesis. Darmstadt University of Technology, Darmstadt, Germany (in German).

Kupfer, A., and H. Müller. 2004. On the taxonomy of ichthyophiid caecilians from southern Thailand: a reevaluation of the holotype of *Ichthyophis supachaii* Taylor 1960 (Amphibia: Gymnophiona: Ichthyophiidae). Amphibia-Reptilia **25:**87–97.

Kupfer, A., A. Kramer, and W. Himstedt. 2004*a*. Sex-related growth patterns in a caecilian amphibian (genus *Ichthyophis*): evidence from laboratory data. Journal of Zoology, London **262:**173–178.

Kupfer, A., J. Nabhitabhata, and W. Himstedt. 2004*b*. Reproductive ecology of female caecilian amphibians (genus *Ichthyophis*): a baseline study. Biological Journal of the Linnean Society:**83:**207–217.

Lamoreux, J., et al. 2003. Value of the IUCN Red List. Trends in Ecology & Evolution **18:**214–215.

Largen, M. J., P. A. Morris, and D. W. Yalden. 1972. Observations on the caecilian *Geotrypetes grandisonae* Taylor (Amphibia Gymnophiona) from Ethiopia. Monitore Zoologico Italiano (Nuova Serie) Supplemento **4:**185–205.

Lim, K. K. P. 1994. Amphibians. Pages 208–212 in P. K. L. Ng and Y. C. Wee, editors. The Singapore red data book—threatened plants and animals of Singapore. The Nature Society, Singapore.

Lips, K. R., J. K. Reaser, B. E. Young, and R. Ibáñez. 2001. Amphibian monitoring in Latin America: a protocol manual. Herpetological Circular **30:**1–115.

Loader, S. P., M. Wilkinson, D. J. Gower, and C. A. Msuya. 2003. A remarkable young *Scolecomorphus vittatus* (Amphibia: Gymnophiona: Scolecomorphidae) from the North Pare Mountains, Tanzania. Journal of Zoology **259:**93–101.

Loveridge, A. 1936. Scientific results of an expedition to rain forest regions in eastern Africa. VII Amphibians. Bulletin of the Museum of Comparative Zoology, Harvard **79:**369–430.

Loveridge, A. 1937. Scientific results of an expedition to rain forest regions in eastern Africa. IX Zoogeography and itinerary. Bulletin of the Museum of Comparative Zoology **79:**481–541.

Maneyro, R., and J. A. Langone. 2001. Categorización de los anfibios del Uruguay. Cuadernos de Herpetologia. **15:**107–118 (in Spanish).

Marsh, D. M. 2001. Fluctuations in amphibian populations: a meta-analysis. Biological Conservation **101:**327–335.

McCoy, E. D. 1994. "Amphibian decline": a scientific dilemma in more ways than one. Herpetologia **50:**98–103.

Measey, G. J. 2004. Are caecilians rare? An East African perspective. Journal of East African Natural History **93:**97–117.

Measey, G. J., and M. Di-Bernardo. 2003. Estimating juvenile abundance in a population of the semi-aquatic caecilian, *Chthonerpeton indistinctum* (Amphibia: Gymnophiona: Typhlonectidae), in southern Brazil. Journal of Herpetology **37:**371–373.

Measey, G. J., D. J. Gower, O. V. Oommen, and M. Wilkinson. 2001. Permanent marking of a fossorial caecilian, *Gegeneophis ramaswamii* (Amphibia: Gymnophiona: Caeciliidae). Journal of South Asian Natural History **5:**141–147.

Measey, G. J., D. J. Gower, O. V. Oommen, and M. Wilkinson. 2003*a*. A mark-recapture study of the caecilian amphibian *Gegeneophis ramaswamii* (Amphibia: Gymnophiona: Caeciliidae) in southern India. Journal of Zoology, London **261:**129–133.

Measey, G. J., D. J. Gower, O. V. Oommen, and M. Wilkinson. 2003*b*. Quantitative surveying of endogeic limbless vertebrates—a case study of *Gegeneophis ramaswamii* (Amphibia: Gymnophiona: Caeciliidae) in southern India. Applied Soil Ecology **23:**43–53.

Meyer, A. H., B. R. Schmidt, and K. Grossenbacher. 1998. Analysis of three amphibian populations with quarter-century long time-series. Proceedings of the Royal Society of London, B **265:**523–528.

Molur, S., and S. Walker. 1998. Conservation assessment of the herpetofauna of India—an overview. Hamadryad **23:**169–178.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature **403:**853–858.

Nussbaum, R. A., and M. E. Pfrender. 1998. Revision of the African caecilian genus *Schistometopum* Parker (Amphibia: Gymnophiona: Caeciliidae). Miscellaneous publications. Museum of Zoology, University of Michigan, Ann Arbor **187:**1–32.

Nussbaum, R. A., and M. Wilkinson. 1989. On the classification and phylogeny of caecilians (Amphibia: Gymnophiona) a critical review. Herpetological Monographs **3:**1–42.

Oommen, O. V., G. J. Measey, D. J. Gower, and M. Wilkinson. 2000. The distribution and abundance of the caecilian *Gegeneophis ramaswamii* (Amphibia: Gymnophiona) in southern Kerala. Current Science **79:**1386–1389.

O'Reilly, J. C. 1996. Keeping caecilians in captivity. Advances in Herpetoculture **1:**39–45.

Padhye, A. D., and H. V. Ghate. 2002. An overview of amphibian fauna of Maharashtra state. Zoos' Print Journal **17:**735–740.

Pechmann, J. H. K., and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective: natural fluctuations and human impacts. Herpetologia **50:**65–84.

Pennisi, E. 2000. Meeting spotlights creatures great and small. Science **283:**623–624.

Pillai, R. S., and M. S. Ravichandran. 1999. Gymnophiona (Amphibia) of India. A taxonomic study. Records of the Zoological Survey of India, Occasional Papers **72:**1–117.

Possingham, H. P., S. J. Andelman, M. A. Burgman, R. A. Medelin, L. L. Master, and D. A. Keith. 2002. Limits to the use of threatened species lists. Trends in Ecology & Evolution **17:**503–507.

Reichle, S., and J. Köhler. 1996. *Caecilia marcusi*. Herpetological Review **27:**208.

Sala, O. E., et al. 2000. Global biodiversity scenarios for the year 2100. Science **287:**1770–1774.

Sarasin, P., and F. Sarasin. 1887–1890. Ergebnisse Naturwissenschaftlicher. Forschungen auf Ceylon. Zweiter Band: Zur Entwicklungsgeschichte und Anatomie der ceylonesischen Blindwühle *Ichthyophis glutinosus*, L. Keidel's Verlag, Wiesbaden (in German).

Semlitsch, R. D., D. E. Scott, J. H. K. Pechmann, and J. W. Gibbons. 1996. Structure and dynamics of an amphibian community. Evidence from a 16-year study of a natural pond. Pages 217–248 in M. L. Cody and J. A. Smallwood, editors. Long-term studies of vertebrate communities. Academic Press, San Diego.

Semlitsch, R. D., editor. 2003. Amphibian conservation. Smithsonian Books, Washington, D.C.

Seshachar, B. R. 1942. The eggs and embryos of *Gegeneophis carnosus* Bedd. Current Science **11:**439–441.

Skelly, D. K., K. L. Yurewicz, E. E. Werner, and R. A. Relyea. 2003. Estimating decline and distributional change in amphibians. Conservation Biology **17:**744–751.

Stocking, M. A. 2003. Tropical soils and food security: the next 50 years. Science **302:**1356–1359.

Subash Peter, M. C., K. K. Sutharam, and O. V. Oommen. 1996. *In vitro* effects of thyroid and gonadal hormones on the activity of mitochondrial oxidative enzymes in a teleost (*Anabas testudineus* Bloch) and an apodan Amphibian (*Gegeneophis carnosus* Beddome). Proceedings of the Indian National Science Academy **2:**71–80.

Taylor, E. H. 1968. The caecilians of the world: a taxonomic review. University of Kansas Press, Lawrence.

Thomas, C. D., et al. 2004. Extinction risk from climate exchange. Nature **427:**145–148.

Travis, J. 1994. Calibrating our expectations in studying amphibian populations. Herpetologia **50:**104–108.

Valdecasas, A. G., and A. I. Camacho. 2003. Conservation to the rescue of taxonomy. Biodiversity and Conservation **12:**1113–1117.

Vijayakumar, S. P., K. Vasudevan, and N. M. Ishwar. 2001. Herpetofaunal mortality on roads in the Anamalai Hills, southern Western Ghats. Hamadryad **26:**253–260.

Wake, M. H. 1984. A new species of *Caecilia* (Amphibia: Gymnophiona) from Bolivia. Amphibia-Reptilia **5:**215–220.

Wake, M. H. 1993. Reproduction in caecilians. Pages 112–120 in W. C. Hamlett, editor. Reproductive biology of South American vertebrates. Springer-Verlag, New York.

Wake, M. H. 1994. Caecilians (Amphibia: Gymnophiona) in captivity. Pages 223–228 in J. B. Murphy, K. Adler, and J. T. Collins, editors. Captive management and conservation of amphibians and reptiles. Society for the Study of Amphibians and Reptiles, Ithaca, New York.

Wake, M. H. 1998. *Dermophis oaxacae* (Mertens). Catalogue of American amphibians and reptiles **661:**1–2.

Wake, M. H. 2002. Caecilians. Pages 38–41 in T. Halliday and K. Adler, editors. The new encyclopedia of reptiles and amphibians. Oxford University Press, Oxford, United Kingdom.

Wake, M. H. 2003. The osteology of caecilians. Pages 1809–1876 in H. Heatwole, editor. Amphibian biology. Volume 5. Osteology. Surrey Beatty and Sons, Chipping Norton, New South Wales.

Wake, M. H., G. Parra-Olea, and J. Sheen. 2004. Biogeography and molecular phylogeny of certain New World caecilians. In M. A. Donnelly, B. I. Crother, C. Guyer, M. H. Wake, and M. White, editors. Ecology and evolution in the tropics: a herpetological perspective. University of Chicago Press, Chicago: in press.

Weldon, C., and L. H. du Preez. 2004. Decline of the Kihansi spray toad, *Nectophrynoides asperginis*, from the Udzungwa Mountains, Tanzania. Froglog **62:**2–3.

Wen, Y. 1998. The current status of *Ichthyophis bannanicus* Yang. Sichuan Journal of Zoology **17:**54.

Wilkinson, M. 1981. Notes on a caecilian, *Nectocaecilia* sp. Herptile **5:**22–25.

Wilkinson, M. 1988. The status of *Nectocaecilia cooperi* Taylor, with comments on the genus *Nectocaecilia* Taylor (Amphibia: Gymnophiona). Journal of Herpetology **22:**119–121.

Wilkinson, M., and R. A. Nussbaum. 1992. Taxonomic status of *Pseudosiphonops ptychodermis* Taylor and *Mimosiphonops vermiculatus* Taylor (Amphibia: Gymnophiona: Caeciliaidae) with description of a new species. Journal of Natural History **26:**675–688.

World Conservation Union (IUCN). 2000. The 1999 list of threatened fauna and flora of Sri Lanka. IUCN, Colombo, Sri Lanka.

World Conservation Union (IUCN). 2003. IUCN red list of threatened species. IUCN, Gland, Switzerland. Available from http://www.redlist.org (accessed November 2003).

World Conservation Union (IUCN), IUCN Species Survival Commission, Conservation International Center for Applied Biodiversity Science, and NatureServe. 2004. IUCN Global Amphibian Assessment. Available from www.globalamphibians.org (accessed October 2004).

Young, B. E., et al. 2001. Population declines and priorities for amphibian conservation in Latin America. Conservation Biology **15:**1213–1223.

Zhao, E.-M. 1998. China red data book of endangered animals.Amphibia and Reptilia. National Environmental Protection Agency, Endangered Species Scientific Commission. Science Press, Beijing.

Appendix. Caecilians and the 2004 Global Amphibian Assessment.

The Global Amphibian Assessment (GAA) is a joint project of the World Conservation Union (IUCN) Species Survival Commission, Conservation International's Center for Applied Biodiversity Science, and NatureServe. It aims to assess the conservation status of all amphibian species globally. The GAA began in 2000 and the first version of the database was released in October 2004 (World Conservation Union et al. 2004). It is hoped that assessments will be reviewed in the future as part of an ongoing program.

Regional workshops were held throughout the world. Those relevant to caecilians were held in Africa (Kenya, April 2002), southern Asia (India, July 2002), Southeast Asia (Thailand, October 2002), South America (Brazil, April 2003; Ecuador, August 2003; Argentina, October 2003), and Central America (Costa Rica, November 2002). At these workshops, the conservation status of every recognized species of amphibian was discussed. Where further work was required, smaller groups were tasked with completing assessments. In view of the paucity of caecilian specialists, regional assessments were often undertaken partly by more general herpetologists or frog and salamander specialists. Assessments for the Seychelles were conducted by correspondence review. After preliminary reviews, all draft assessments were finalized during a 3-day meeting of conservation and caecilian specialists held at The Natural History Museum, London, in February 2004.

Current IUCN criteria and categories were used to categorize the status of each species. Where possible, distribution maps were produced within a geographic information system (GIS) framework.

A total of 167 caecilian species were assessed (Table 1). In identifying 25 world biodiversity hotspots, Myers et al. (2000) report that the proportion of amphibians endemic to these areas (54%) is higher than for tetrapods as a whole (35%). Although distribution data for all caecilians are imprecise, we estimate that more than two-thirds of species are endemic to these 25 hotspots.

There was notable disparity in the assessed status of caecilians among major geographic regions. For example, many southern Asian caecilians were recorded as threatened at the first-draft stage, whereas most Southeast Asian species were data deficient, even where the level of knowledge was comparable. In these cases disparity was interpreted largely as uneven treatment rather than as a real difference in knowledge, and greater evenness in assessments was introduced at later stages.

Although many have not been reported for many years, no caecilian species are known to be extinct. The only caecilian species listed as endangered is the Seychellean caeciliid *Grandisonia brevis*, which is known only from a few localities in a small area in which its apparent habitat is undergoing decline. The three vulnerable species (Table 1) are the Sri Lankan ichthyophiids *Ichthyophis orthoplicatus* and *I. pseudangularis*, along with the Seychellean caeciliid *Praslinia cooperi*. Although the proportion of data-deficient species is large for all geographic regions (except the Seychelles) and families, it is notably the largest for uraeotyphlids and ichthyophiids of southern and Southeast Asia. Knowledge of the conservation status of these groups (especially the large family Ichthyophiidae) is particularly affected by confused taxonomy. Improving the taxonomy of these groups is a research priority.

Most species listed as data deficient are known from very few specimens and require further taxonomic investigation. Several species with reportedly large distributions are listed as data deficient because they are taxonomically problematic and voucher specimens are not reported or have not been verified. Most species listed as least concern were done so on the basis of seemingly large geographic distribution rather than knowledge of population sizes and trends. Other least-concern species are known from smaller distributions but have been collected from secondary habitats, demonstrating some degree of adaptability. Some species listed as least concern are of doubtful taxonomic validity. For example, the Southeast Asian ichthyophiid *Ichthyophis kohtaoensis* is recorded from much of Thailand and peninsular Malaysia, but the type material was collected from the small Gulf of Thailand island Koh Tao, and the referral of at least some of the material from the mainland requires reassessment (e.g., Kupfer et al. 2004*a,* 2004*b*). A restricted concept of *I. kohtaoensis* may have important implications for future assessments of this species.

There are several differences in status from previous, mostly national level assessments. For example, in a previous assessment (summarized by Molur & Walker 1998) the Indian caeciliid *Gegeneophis ramaswamii* was considered endangered, based on the belief that it was forest dependent and known from only two localities. It is now listed as least concern based on a clearer understanding of taxonomy, adaptability,

Table 1. Summary of the data on caecilians in the 2004 Global Amphibian Assessment.

	Species	*Number of data deficient (%)*	*Least concern (%)*	*Vulnerable (%)*	*Endangered (%)*
Region					
Southeast Asia	26	24 (92)	2 (8)	0	0
Southern Asia	25	19 (76)	4 (16)	2 (8)	0
Africa	21	11 (52)	10 (48)	0	0
Seychelles	6	0	4 (66)	1 (17)	1 (17)
South America	73	46 (63)	27 (37)	0	0
Central America*	16	9 (56)	7 (44)	0	0
Total	167	109 (65)	54 (32)	3 (2)	1 (1)
Family					
Rhinatrematidae (South America)	9	5 (56)	4 (44)	0	0
Ichthyophiidae (southern & Southeast Asia)	39	32 (82)	5 (13)	2 (5)	0
Uraeotyphlidae (India)	5	5 (100)	0	0	0
Scolecomorphidae (Africa)	6	3 (50)	3 (50)	0	0
Caeciliidae (not Southeast Asia)	94	55 (59)	37 (39)	1 (1)	1 (1)
Typhlonectidae (South America)	14	9 (64)	5 (36)	0	0

**The few species present in Central America that also extend into northern South America were arbitrarily recorded as Central American.*

and distribution (Oommen et al. 2000). Another Indian caeciliid, *Indotyphlus battersbyi*, is now data deficient rather than critically endangered because of uncertainty over its distribution and ecological requirements. A national assessment (Zhao 1998) lists the Chinese ichthyophiid *Ichthyophis bannanicus* as endangered, claiming that the total population declined from about 5000 before the 1960s to 400 in 1986, although no source for these data is given. Chou Wenhao reported to a GAA workshop that about 200 individuals were collected in a single night in the Xishuangbanna National Reserve in 2000. In view of its apparently large distribution and evidence that it tolerates some habitat disturbance, the new assessment for *I. bannanicus* is "least concern."

The overwhelming picture that comes from an overview of the GAA caecilian data is the severe lack of information. Two-thirds of species are data deficient and most of the remaining third are least concern because of lack of evidence of threats and declines rather than positive evidence of stable populations. Although the GAA data for frogs and salamanders are not yet complete, it is clear that the proportion of data-deficient species is substantially lower than for caecilians.

It is not possible to list here all those who contributed to the caecilian assessments. A full list of contributors can be found for each species in the Global Amphibian Assessment database released in October 2004 (World Conservation Union et al. 2004).

Authors of Appendix

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