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Global amphibian declines: a perspective from the Caribbean

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Recent concern over the possibility of a global decline in amphibians prompted this assessment of the West Indian species. At the species level, the West Indian amphibian fauna (156 species, all frogs and toads) has not undergone a general decline, and no species is known to be extinct. However, one Puerto Rican species (*Eleutherodactylus karlschmidti*) has not been seen in over ten years despite considerable search effort. Seven other species, including the Puerto Rican live-bearing frog (*E. jasperi*), have not been seen recently, although their present status cannot be determined until additional effort is made to locate them. Two stream-associated species on Hispaniola (*E. semipalmatus* and *Hyla vasta*) appear to have declined in recent years, probably due to the alteration of riparian habitats by deforestation. Other vertebrate groups in the West Indies, such as mammals, have been more affected by human-caused environmental degradation than have amphibians. Large-scale extinctions of frogs and other forest-dwelling species are not expected to occur until forest cover reaches very low levels. Haiti is on the brink of such extinctions with less than 1% of its forest cover remaining. Two recommendations are made to help curtail the expected loss of biodiversity: (i) import charcoal to replace that produced by burning native trees (used as cooking fuel), as an immediate measure, and (ii) control human population growth, as a long-term solution.

Keywords: West Indies; frog; extinctions

Introduction

The status of the Earth's amphibian populations has recently become a concern amid reports that some species are declining or have disappeared (Phillips, 1990; Wake, 1991). Although it is widely recognized that many plant and animal species are being eradicated as a result of deforestation in the tropics (Myers, 1988; Wilson, 1988), amphibians have been singled out because at least some species seem to be disappearing from pristine, unaltered areas. Unfortunately, most of the information on amphibian decline is anecdotal, and this is especially true for tropical species, which represent more than 90% of the Earth's 4100 amphibian species. Here I review the current situation regarding global amphibian declines and present new data on the status of a tropical amphibian fauna, the frogs and toads of the West Indies.

Global amphibian declines

Reports of declining amphibian populations during the late 1980s at scattered sites throughout the world generated concern that a global phenomenon was taking place (Barinaga, 1990; Blaustein and Wake, 1990; Phillips, 1990). Among temperate sites,

most reports came from the western USA and included several species of toads (*Bufo boreas, B. canorus*) and frogs (*Rana aurora, R. cascade, R. muscosa and R. pretiosa*). Of the tropical sites, most attention focused on declines in unaltered rain forest habitats of Costa Rica where several amphibians appear to have declined (Jacobson and Vandenberg, 1991; Wake, 1991; Crump *et al.*, 1992). Declines from unaltered habitats also were seen at sites in southeastern Brazil (Heyer *et al.*, 1988) and in Australia (Blaustein and Wake, 1990; Czechura and Ingram, 1990). Other regions, such as the southeastern USA, the Amazonian basin and Andean slopes of South America, central Africa, southeast Asia, Borneo, and the Philippines have had few or no declines thus far.

Unfortunately, a major difficulty in assessing these reported declines of amphibians has been the virtual absence of long-term baseline data on population levels. Without knowing the degree of natural population fluctuations it is impossible to distinguish between normal and abnormal declines. For example, one long-term study of four species of amphibians (three salamanders and a frog) at a site in the southeastern USA showed that normal fluctuations can be considerable, but that there was no evidence of a recent downward trend in the abundance (Pechmann *et al.*, 1991). No such rigorous long-term study is available yet for a tropical site, although two reports have been based on long-term observations. In a 35-year study, Heyer *et al.* (1988) noted population declines and extinctions of amphibians at several localities in southeastern Brazil which they attributed to an unusually heavy frost in 1979. Crump *et al.* (1992) reported that a species of toad (*Bufo periglenes*) in Costa Rica underwent a drastic reduction in numbers after 1987. They suggested that the decline might be the result of slightly warmer water temperatures of the breeding pools coupled with reduced precipitation.

In an effort to obtain more information regarding the status of the Earth's amphibians, the International Union for the Conservation of Nature (IUCN) established a Declining Amphibian Populations Task Force (DAPTF) in 1991. The DAPTF is based in Corvallis, Oregon, and has a full-time coordinator (Dr James L. Vial), an international board of directors, and regional 'working group chairs'. The objective of DAPTF is to establish a global monitoring programme to assess the status of amphibian populations. Standardized survey methods will be used so that valid comparisons can be made among different sites, and computer data bases containing this information will be available to interested persons. Anyone desiring more information on DAPTF can contact the coordinator (Center for Analysis of Environmental Change, EPA Environmental Laboratory, 200 Southwest 35th Street, Corvallis, OR 97333, USA).

Caribbean amphibians

The islands of the West Indies have an unusually high density of amphibian species for an area that is approximately the size of Great Britain. Remarkably, the number of endemic species (156), all frogs and toads, is almost twice as large as the number of such species inhabiting all of North America and Europe combined (86). One genus *Eleutherodactylus* (Leptodactylidae), dominates the West Indian frog fauna with 133 species. They are terrestrial-breeding frogs that lay eggs on land, often far away from water, and these eggs later hatch into miniatures of the adults (i.e., no tadpoles). The entire life cycle can take place high in a tree, in a cave, or on a mountain top, which explains the enormous evolutionary success of these frogs. The remaining species are divided among

three groups of aquatic-breeders: toads (*Peltaphryne*), tree frogs (Hylidae) and stream frogs (*Leptodactylus*).

In recent years, I have had the opportunity to determine the current status of nearly all West Indian amphibian species by direct field observations. Such information on the status of tropical amphibian species generally is unavailable because most have small ranges and occur in remote areas that are difficult to reach. Often, twenty or more years may pass before a particular species is sought or encountered. The information presented here was assembled to determine whether a general decline has occurred in the West Indies and, if so, to identify any patterns that might suggest a common cause.

Materials and methods

Fieldwork was conducted in Cuba (1988–1992), Jamaica (1981–1990), Hispaniola (1983–1991), Puerto Rico (1983–1990) and the Lesser Antilles (1984–1991). No species of amphibian is endemic to the Bahamas. Data are presented as the year that a species was last reported, which means that a specimen was collected and preserved, or that the record is based only on vocalization (if noted). Nearly all preserved specimens are in the collection of the United States National Museum (Smithsonian Institution). Some recently-collected specimens are in the collections of the Museo Nacional de Historia Natural (Havana, Cuba) or in the author's collection.

Results

All species of native West Indian amphibians (frogs and toads) are shown in Table 1 along with the year that they were last reported. Except for a few species discussed below, the last reported record was also the last time that the species was sought. For example, *Eleutherodactylus sciagraphus* was last seen eight years ago, in 1984. However, no herpetologist has since visited that remote region of southwestern Haiti to collect it and, therefore, the species is presumed to be extinct (no information is available to indicate otherwise). As a general rule, any species seen in 1984 or later in Table 1 should be considered as extant, except as discussed below.

Nearly all (148 = 95%) species of native West Indian amphibians have been encountered since the mid-1980s, and most of those during the last three years. This indicates that there has not been a recent major decline in West Indian amphibians at the species level. However, it is important to focus on those species that have not been seen recently and explore the possible reasons for their absence.

Cuba

All of the 45 species of Cuban frogs have been encountered in recent years. There is no information which indicates that any Cuban species of anuran is declining or has disappeared.

Hispaniola

Out of 63 Hispaniolan frog species, three species of *Eleutherodactylus* and one toad (*Peltaphryne*) have not been encountered recently. I did not visit the range of *P. fluviatica*, although at least one recent attempt to collect this species was not successful (R. Powell, personal communication). However, this species occurs in a relatively xeric

Table 1. Last reported records of native West Indian amphibians

Species	Year	Species	Year	Species	Year
Cuba		Hispaniola		Jamaica	
Peltaphryne cataulaciceps	1987[a]	*Peltaphyryne fluviatica*	1971[e]	*Calyptahyla crucialis*	1985
P. empusa	1984[b]	*P. guentheri*	1991[f]	*Eleutherodactylus alticola*	1984
P. fustiger	1991	*Eleutherodactylus abbotti*	1991	*E. andrewsi*	1988
P. gundlachi	1992	*E. alcoae*	1991[f]	*E. cavernicola*	1984
P. longinasus	1989	*E. amadeus*	1991	*E. cundalli*	1985
P. peltocephalus	1992	*E. apostates*	1991	*E. fuscus*	1984
P. taladai	1990	*E. armstrongi*	1991	*E. glaucoreius*	1988
Eleutherodactylus acmonis	1989	*E. audanti*	1991	*E. gossei*	1990
E. albipes	1989	*E. auriculatoides*	1986	*E. grabhami*	1985
E. atkinsi	1992	*E. bakeri*	1991	*E. griphus*	1985
E. auriculatus	1992	*E. brevirostris*	1991[c]	*E. jamaicensis*	1987
E. bartonsmithi	1989	*E. caribe*	1991	*E. junori*	1985
E. bresslerae	1989	*E. chlorophenax*	1985	*E. luteolus*	1988
E. cubanus	1989	*E. counouspeus*	1991	*E. nubicola*	1990
E. cuneatus	1992	*E. corona*	1991	*E. orcutti*	1985
E. dimidiatus	1992	*E. darlingtoni*	1985	*E. pantoni*	1990
E. eileenae	1992	*E. dolomedes*	1991	*E. pentasyringos*	1988[c]
E. emiliae	1990[c,d]	*E. eunaster*	1984	*E. sisyphodemus*	1984
E. etheridgei	1988	*E. flavescens*	1991	*Hyla marianae*	1985
E. greyi	1989	*E. fowleri*	1985	*H. wilderi*	1985
E. guanahacabibes	1992	*E. furcyensis*	1985	*Osteopilus brunneus*	1990[c]
E. guantanamera	1990	*E. glandulifer*	1991	*O.* sp. nov.	1987[c]

Table 1. Continued

Species	Year	Species	Year	Species	Year
E. gundlachi	1990	*E. glanduliferoides*	1985		
E. intermedius	1989	*E. glaphycompus*	1991		
E. ionthus	1990	*E. grahami*	1991	Puerto Rico Bank	
E. klinikowskii	1991[c]	*E. haitianus*	1986	*Eleutherodactylus antillensis*	1991[c]
E. leberi	1990[c]	*E. heminota*	1991	*E. brittoni*	1991[c]
E. limbatus	1991[c]	*E. hypostenor*	1984	*E. cochranae*	1991[c]
E. mariposa	1990	*E. inoptatus*	1991	*E. cooki*	1991[c,g]
E. melacara	1989	*E. jugans*	1985	*E. coqui*	1991[c,g]
E. pezopetrus	1989	*E. lamprotes*	1991	*E. eneidae*	1990[c]
E. pinarensis	1990	*E. leoncei*	1991	*E. gryllus*	1991[c]
E. planirostris	1992	*E. lucioi*	1979[e]	*E. hedricki*	1991[c]
E. ricordii	1990	*E. minutus*	1986	*E. jasperi*	1981[c,g]
E. ronaldi	1990	*E. montanus*	1986	*E. karlschmidti*	1970s[g]
E. sierramaestrae	1990	*E. neodreptus*	1964[e]	*E. lentus*	1974[h]
E. symingtoni	1988	*E. nortoni*	1985	*E. locustus*	1991[c]
E. thomasi	1990[d]	*E. oxyrhynchus*	1991	*E. monensis*	1990[g]
E. toa	1990	*E. parabates*	1986	*E. portoricensis*	1991[c]
E. turquinensis	1990	*E. parapelates*	1984	*E. richmondi*	1990[i]
E. varians	1992[c]	*E. patricae*	1986	*E. schwartzi*	1990[c,j]
E. varleyi	1991[c]	*E. paulsoni*	1991	*E. unicolor*	1991[c]
E. zeus	1990	*E. pictissimus*	1991	*E. wightmanae*	1991[c]
E. zugi	1991	*E. pituinus*	1986	*Leptodactylus albilabris*	1991[c]
Osteopilus septentrionalis	1992[c]	*E. poolei*	1985		
		E. probolaeus	1985		
		E. rhodesi	1985	Lesser Antilles	
		E. rufifemoralis	1985	*Eleutherodactylus barlagnei*	1985[k]
		E. ruthae	1991	*E. johnstonei*	1991

E. schmidti	1986	*E. martinicensis*	1991
E. sciagraphus	1984	*E. pinchoni*	1985[k]
E. semipalmatus	1985	*E. urichi*	1991[k,l]
E. sp. 'S'	1991	*Leptodactylus fallax*	1991
E. thorectes	1991	*L. wagneri*	1991[k]
E. ventrilineatus	1991		
E. warreni	1970[e]		
E. weinlandi	1991[f]		
E. wetmorei	1991		
Leptodactylus dominicensis	1991		
Hyla heilprini	1985		
H. pulchrilineata	1991		
H. vasta	1988[f]		
Osteopilus dominicensis	1991		

[a]Julio Novo (Academy of Sciences, Cuba), personal communication.
[b]Garrido *et al.* (1986).
[c]Vocalization record (by the author, if not otherwise noted).
[d]Alberto R. Estrada (Flora and Fauna, Cuba), personal communication.
[e]Known only from the type series.
[f]Robert Powell (Avila College), personal communication.
[g]Richard Thomas (University of Puerto Rico), personal communication.
[h]Jones (1982).
[i]Woolbright, (1991).
[j]Gregory Mayer (University of Wisconsin), personal communication.
[k]Ronald I. Crombie (Smithsonian Institution), personal communication.
[l]Robert W. Henderson (Milwaukee Public Museum), personal communication.

area where heavy rains are infrequent, and it was such an unusual event that led to the collection of the original series in 1971 (Schwartz, 1972). It was not encountered at that locality on visits prior or subsequent to that time (A. Schwartz, personal communication). It may be difficult to determine the status of this species unless one is fortunate enough to be present during the necessary climatic conditions (see also *P. lemur*, discussed below).

The single known locality of *E. lucioi* on the remote Presquile du Nord Ouest of Haiti was not visited, but the single known locality of *E. neodreptus* was visited briefly in 1985 and no specimens were encountered. Additional fieldwork in that region of the Sierra de Baoruco is needed before any conclusions can be drawn regarding the status of *E. neodreptus* (known from only a single specimen). Ile de Tortue, Haiti, was not visited during recent fieldwork and, therefore, no current information is available on *E. warreni*, which remains known only from the type series collected in 1968 and 1970 (Schwartz, 1976).

Two species of frog associated with streams appear to be reduced in numbers from previous years. Although the semi-aquatic *E. semipalmatus* was collected at one remote site in the Massif de La Selle in 1985 by a group from the University of Florida, it has not been taken recently at other localities, including Furcy (Haiti) where it was found to be abundant in the 1950s and 1960s (Shreve and Williams, 1963; A. Schwartz, personal communication). Also, *Hyla vasta* was taken at only one locality on one trip despite our 19 man-months of collecting on Hispaniola over the past eight years (it also has been taken recently at one locality in the Dominican Republic, near Paraiso; Robert Powell, personal communication). This species was more abundant in the 1960s and 1970s (A. Schwartz, R. Thomas, personal communications). Adults have been found inside the axils of banana plants, but they lay eggs in quiet pools along streams (Noble, 1927). These riparian habitats in Hispaniola now have been highly altered by deforestation. The removal of forest results in frequent flooding with intervening dry periods, and the stream beds are clogged with mud and debris. It is likely that deforestation has affected these stream-associated anurans more than other species.

Jamaica

All 22 native Jamaican frog species have been encountered since the mid-1980s. However, several species are of possible concern. The semi-aquatic *E. orcutti* was last encountered in 1985, but it was not seen at several known localities around Hardwar Gap (St Andrew and Portland Parishes) on two subsequent trips (1987 and 1988). This species also is known from localities in the Rio Grande River drainage south of Port Antonio (Schwartz and Henderson, 1991) and those additional localities should also be checked.

Four other Jamaican species (*Eleutherodactylus cavernicola, E. fuscus, E. junori* and *E. sisyphodemus*) are very restricted in distribution and have not been found commonly within their limited ranges. Deforestation and human encroachment in those areas, combined with the specialized habitat requirements of the species, are probable reasons for their apparent lack of abundance. An additional threat to the native Jamaican anurans may be competition from the introduced frog species *E. johnstonei* and *E. planirostris* which now are widespread and abundant throughout most of the island (Schwartz and Henderson, 1991). The call of *E. johnstonei* is quite loud and may

dominate over the relatively weak vocalizations of some small native species (e.g., *E. junori*, personal observations).

Puerto Rico Bank

A total of 19 species of frog occur on the Puerto Rico Bank (Puerto Rico and the Virgin Islands) and neighbouring Mona Island. The frog fauna of Puerto Rico has received more attention than that of the other islands, and the species generally occur in more accessible areas. Therefore, we have a much clearer picture of the status of Puerto Rican frogs. Studies specifically concerned with the status of these species are underway (Joglar and Burrowes, 1991; Burrowes and Joglar, 1991) and other information on these species has been presented elsewhere (Hedges and Thomas, 1991).

The native toad, *Peltaphryne lemur*, is a burrowing species that occurs in lowland areas and is known from only a few localities (Schwartz and Henderson, 1991). Because of the small number of known specimens, it was, until recently, considered to be in danger of extinction, and captive breeding programmes were instituted at two zoological parks in North America. However, heavy rains in southwestern Puerto Rico in 1984 brought out large numbers (> 1500) of breeding adult toads in Guanica State Forest (Moreno, 1989). The apparent rarity of this species was at least partly due to this unusual reproductive cycle tied to infrequent and heavy rains, combined with its secretive habits. Despite the large numbers of animals seen during the mid-1980s at Guanica, the size of breeding aggregations has declined in the last three years (M. Canals, personal communication). It is likely that the distribution of *P. lemur* is very restricted because most other suitable lowland areas in Puerto Rico are under cultivation or urbanization and are unlikely to support populations of this toad.

Only two of the native Puerto Rican *Eleutherodactylus* have not been seen in recent years. In the case of *E. karlschmidti*, known localities where the species occurred abundantly in the 1960s and 1970s have been searched repeatedly during the last decade by myself and other herpetologists and no evidence of this species has been found. The disappearance of *E. karlschmidti* has no obvious explanation. Some of the localities are in protected and unaltered forest (Caribbean National Forest) on El Yunque. However, rats and mongooses, which were introduced, are abundant in Puerto Rico and occur in undisturbed forest. Black Rats (*Rattus rattus*) especially are a problem in Caribbean National Forest where they are very common, even in the dwarf forest on El Yunque Peak. It is possible that these arboreal nocturnal omnivores prey on *Eleutherodactylus* eggs or the frogs themselves. The mongoose (*Herpestes auropunctatus*), although primarily diurnal, is known to prey on frogs (Walker, 1975; Nellis and Everard, 1983) and this particular species of frog would be especially vulnerable because it characteristically sits on exposed rocks in and around streams (Rivero, 1978). All other species of Puerto Rican frog are partly or completely arboreal except for a common (but secretive) aquatic species (*Leptodactylus albilabris*) and a forest-floor species (*E. richmondi*) that is also believed to be declining (Joglar and Burrowes, 1991). If these introduced predators are responsible for the disappearance of *E. karlschmidti* or the decline of other species such as *E. richmondi* and possibly *E. eneidae*, it is unclear why the decline has occurred recently and not many years ago (before 1900) when the predators were introduced, although invasion of the forest on El Yunque may not have occurred immediately following introduction.

The other species that has not been seen recently is the ovoviviparous frog *E. jasperi*.

It is a small bromeliad-dwelling species known from only three localities in east–central Puerto Rico (Drewry and Jones, 1976). Unlike *E. karlschmidti*, the disappearance of *E. jasperi* is not well established. Ironically, the listing of *E. jasperi* as a threatened species (under the US Endangered Species Act) in 1977 may be the primary reason for our lack of knowledge of this species. Field-oriented systematic studies are the primary source of information on biodiversity and the conservation status of species (Hedges and Thomas, 1991), and those studies initiated since 1977 have not included *E. jasperi* because of the restrictions on collecting associated with the official listing of this species. Consequently, no additional specimens have been collected since that time. Bromeliad-dwelling frogs, especially small *Eleutherodactylus*, are difficult to observe without disassembling the bromeliad because they often hide between leaves deep within the plant and therefore it is difficult to make casual, non-disruptive observations. It is possible that this species has not disappeared and is more widely distributed. Current efforts to locate *E. jasperi* (Burrowes and Joglar, 1991) should help to better assess the status of this species.

One long-term population study has been conducted on several species of Puerto Rican *Eleutherodactylus* (Woolbright, 1991) in Caribbean National Forest. No recent declines were found, except as a direct effect of Hurricane Hugo. Even in those cases, recovery to pre-hurricane levels was found to be quite rapid.

No recent record exists for one of the two endemic frogs of the Virgin Islands, *E. lentus*. The last confirmed record of this species was in 1974 (Jones, 1982) but it was considered to be common (no dates mentioned) by MacLean (1982). Despite the absence of recent records, there is no reason to believe that *E. lentus* has disappeared or has declined (G. Mayer, personal communication).

Lesser Antilles

All six species of frog in the Lesser Antilles have been seen in recent years with no apparent declines. However, the large 'mountain chicken' (*Leptodactylus fallax*) of Montserrat and Dominica is heavily hunted for food (Johnson, 1988) and this appears to be a major factor affecting the abundance of this species.

Discussion

The conclusion from this review is that the West Indian frog fauna has not undergone a general decline. No species is known to be extinct, although one Puerto Rican species (*Eleutherodactylus karlschmidti*) has not been seen in recent years despite efforts to locate it. Insufficient information exists on the other seven species that have not been seen recently to draw any conclusions regarding their status.

The following have been suggested as possible factors responsible for the apparent decline of amphibian populations in various parts of the world: habitat destruction (including mining and logging), introduction of predators and competitors, pollution from pesticides, acid precipitation, increased levels of ultraviolet radiation, human predation, and general climate change (Wake, 1991). Besides these factors, an apparent decline in abundance may be due to natural long-term population fluctuations (Pechmann *et al.*, 1991).

Of the West Indian frog species that appear to be declining in numbers, acid rain and pesticides are probably not significant factors. It is unlikely that increased levels of ultraviolet radiation, as a result of ozone degradation, would have a direct effect on any

West Indian frog species because none is normally active during daylight hours and exposed to direct sunlight. The eggs of the aquatic-breeding frogs, the hylids and bufonids, may be exposed to sunlight but there is no information on egg mortality in those species.

Human consumption appears to be a concern only with the large leptodactylid species *Leptodactylus fallax* on Montserrat and Dominica. No obvious major climatic shift has occurred in the West Indies in recent years (such as a general warming or drying trend) that would cause a decline in amphibian species, although data necessary to evaluate such an effect (detailed information on the physiological ecology of each species) are unavailable. No information is available to indicate that introduced predators are having an adverse effect on the native West Indian frogs, although this may be a factor involved in the disappearance and decline of two Puerto Rican species (*E. karlschmidti* and *E. richmondi*, respectively). Anecdotal information suggests that one of the introduced species of *Eleutherodactylus* on Jamaica (*E. johnstonei*) may be competing with native species but there is no evidence that competitive interactions are responsible for any declines.

Deforestation

The single major factor responsible for the decline of the Earth's amphibians and other organisms is habitat destruction. Approximately 65% of tropical forests have been destroyed by humans, and a reasonable assumption is that forest-associated animals such as amphibians have declined proportionately in numbers of individuals. The West Indies have suffered much more than most other areas: present forest cover estimates for the Greater Antilles are: 13.2% (Cuba), 10% (Dominican Republic), 10% (Puerto Rico), 5% (Jamaica) and <1% (Haiti) (Johnson, 1988; Caribbean/Central American Action, 1990; Paryski *et al.*, 1989; World Resources Institute, 1992; A. Perera, personal communication).

This severe reduction in amphibian habitat (and presumably in population sizes) has not yet had a major effect on the survival of the native species (Table 1). However, the decline in species, unlike the decline in individuals, is not expected to be a linear function of the decline in forest cover. Instead, any given species will continue to exist until the last individual of that species dies. Thus, the number of extant species should not show significant decline until forest cover levels become very low, at which time sudden and catastrophic loss of species will occur. Some extinctions will occur prior to that point due to unequal rates of deforestation in different areas. Following the extinction spasm, some species that can survive without forest cover will continue to exist. Although not included on Myers' list (Myers, 1990), Haiti should be considered one of Earth's 'hot-spots' for biodiversity because of its high level of endemism and critically low level of forest cover.

On Hispaniola, the only two species that appear to have declined in recent years (*Eleutherodactylus semipalmatus* and *Hyla vasta*) are both associated with streams, and the Jamaican aquatic species (*E. orcutti*) also may be declining. It is likely that these aquatic or semi-aquatic species have been affected more than others because of the degradation of watershed (deforestation) and its impact on stream flow. The decline of the Puerto Rican aquatic species, *E. karlschmidti*, was probably not the result of watershed degradation because much of its habitat, especially on El Yunque, remains unaltered.

Compared with other vertebrate groups in the West Indies, amphibians have been affected the least by human-caused environmental degradation. Reptiles (Schwartz and Henderson, 1991), birds (Greenway, 1967; Sibley and Monroe, 1990), and mammals (Morgan and Woods, 1986) have experienced extinctions as a result of human activities yet no amphibian is known to be extinct (current information is unavailable on the status of fresh-water fishes, although no extinctions have been reported; Lee *et al.*, 1983). The West Indian mammal fauna, especially, has been devastated by human-caused extinctions. Out of 82 mammal species that existed when Columbus arrived in the West Indies, 19 (23%) have since become extinct (Morgan and Woods, 1986). Many others were already extinct before the Europeans arrived as a result of activities by the Amerindians (Steadman *et al.*, 1984; Woods and Eisenberg, 1989). This would seem to indicate that Caribbean amphibians are relatively poor 'bioindicators' compared with other vertebrate groups.

Nonetheless, when the final 1% of Haitian forest is destroyed, probably within the next decade (Paryski *et al.*, 1989), it is very likely that most amphibian species will become extinct, along with most of the remaining native fauna. Considering the large number of endemic Haitian species, Haiti may become the Earth's first major biodiversity disaster.

Recommendations

Because of the very low levels of natural cover remaining in the West Indies, it is imperative that deforestation be halted as soon as possible to prevent major losses of amphibians and other species. In the Dominican Republic and Haiti, and to a lesser degree Cuba and Jamaica, a major reason for the felling of trees is the production of charcoal used in cooking. Trees of all types and sizes are cut and brought to a nearby excavated site where the charcoal is produced. If not used locally, it is sold and distributed to other parts of the country. In Haiti, it is common to see overloaded vehicles transporting large sacks of charcoal. Few statistics are available, but it is estimated that 45% of Dominicans use firewood and charcoal for cooking, and in one year (1985) alone, 26 billion kilograms of charcoal were consumed in the Dominican Republic (Ottenwalder, 1989).

An immediate solution to this problem is to replace charcoal with another type of cooking fuel in these countries, especially in Haiti. However, electricity is generally unvailable and most other types of fuel would require special equipment. A less costly and more practical option would be to replace the native charcoal with imported charcoal made from abundant northern conifers. The imported charcoal would not require special equipment, and if effectively distributed, could bring a nearly immediate halt to the deforestation. This would 'buy time' for other long-term measures to be developed and implemented. Of course, for this proposal to be implemented outside funding would have to be obtained for the imported charcoal so that it could be distributed freely within the country.

The most obvious long-term solution to the deforestation problem in the West Indies is population control. Human population densities on West Indian islands, especially Jamaica (227 km^{-2}), Haiti (236 km^{-2}), Puerto Rico (368 km^{-2}) and Barbados (593 km^{-2}) are among the highest on Earth (Caribbean/Central American Action, 1990; World Resources Institute, 1992). For comparison, the average population densities in tropical South America and in Central America are 18 km^{-2} and 48 km^{-2}, respectively. Birth

rates in the West Indies are also proportionately high, and only 10% of Haitians practice contraception of any type (World Resources Institute, 1992). This figure is higher for Dominicans (50%) and Jamaicans (55%). Unless some form of population control is implemented in these countries, demands on the environment will only become greater in the future.

Finally, more systematic surveys of the existing biodiversity in the West Indies are needed. Such surveys are important in establishing the critical areas that are in immediate need of protection (Raven and Wilson, 1992). Currently, the few amphibian populations being monitored on a regular basis are in Puerto Rico. Efforts should be made to begin monitoring populations on the other islands so that we have a more accurate gauge of the health of Caribbean amphibians.

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