The conservation status of amphibians in the West Indies

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Abstract. There are 196 species of amphibians known from the West Indies, 188 of which are native. With only a few exceptions, all of those native species are endemic to single islands or island banks and most are restricted to a small region within an island such as a single mountain top. The native species are members of the following families: Aromobatidae (1 species), Bufonidae (12 sp.), Hylidae (9 sp.), Eleutherodactylidae (161 sp.), Leptodactylidae (3 sp.), and Strabomantidae (2 sp.). The recent Global Amphibian Assessment found that 84% of West Indian amphibian species are threatened and that 71% are in the two highest threat categories, Endangered and Critically Endangered. The remote areas where many species occur constrain monitoring efforts, but remarkably, 49 species (26% of all native species) have not been observed in at least 10 years and 31 species (16%) in at least 20 years. Much-needed surveys will almost certainly find some of those species, but five species have not been found despite intensive search efforts, and are likely extinct — for unknown reasons. Small distributions and declining habitat area and quality were the most important considerations in determining conservation status. Many species are contained within national parks and other protected areas, but the effectiveness of the protected areas varies from essentially no protection to moderately good protection. Unfortunately, most of the critically endangered species occur in countries (e.g., Haiti) where protected areas have low effectiveness. Deforestation and habitat modification continue to be the most serious and widespread threats, although the impacts of an introduced fungal pathogen and climate change are being carefully monitored. For unexplained reasons, the largest conservation agencies, The Nature Conservancy and Conservation International, have yet to establish programs of any significance in countries of the Caribbean region (e.g., Haiti) where the biodiversity crisis is the most severe. Nearly all of the biological data used in determining the conservation status of species comes from the field of systematics and taxonomy rather than ecology, yet this fact has yet to be fully appreciated by the culture of conservation.

Key words: Antilles; biodiversity; Caribbean; deforestation; ecology; extinction; genetic resources; systematics; taxonomy.

Introduction

The West Indies are located between North and South America and are similar in total land area to Great Britain. There is some variability in how the biogeographic region is defined, but most biologists describe it as including the islands of the Bahamas Bank, the Greater Antilles (Cuba, Jamaica, Hispaniola, and Puerto Rico), the Lesser Antilles, and the Cayman Islands. It has become acceptable to refer to the same region as the “Caribbean Islands” (Smith et al., 2005), although technically that label is not correct because the islands of the Bahamas Bank are in the Atlantic Ocean, not the Caribbean Sea. Details of the physical geography of the West Indies and the historical and ecological biogeography of West Indian amphibians are reviewed elsewhere (Hedges, 1996, 1999, 2006b; Iturralde-Vinent and MacPhee, 1999).

The climate of the West Indies is influenced by prevailing winds from the northeast, bringing moisture primarily to the northern and eastern areas of each island. Forests originally covered virtually all parts of all islands, but approximately 90% of those original forests have been destroyed by humans (Hedges and Woods, 1993; Smith et al., 2005). Like most terrestrial organisms in the tropics, amphibians are essentially forest-dwelling animals. Therefore the decimation of the West Indian forests has greatly reduced the area of available habitats for amphibians, regardless of their abundance within existing habitats.

There are 196 species of amphibians known from the West Indies, 188 of which are native (Hedges, 2010; Henderson and Powell, 2009) (table 1). Additional undescribed species on Cuba, Jamaica, Hispaniola, and Puerto Rico are known to us, and we suspect that the actual number of West Indian amphibians, when all are finally discovered and described, is likely to exceed 300 species. All, or nearly all, of the native species are endemic to the region, and, with few exceptions, individual species are endemic to single islands or island banks. Many are restricted to a small area within an island or single mountain top. Of the native amphibians, there is one aromobatid (volcano frog), 12 bufonids (toads), 9 hylids (treefrogs), 161 eleutherodactylids (direct-developing terrestrial frogs), 3 leptodactylids (ditch frogs), and 2 strabomantids (direct-developing terrestrial frogs). Most species have been included in molecular phylogenies, and the taxonomy used here follows that in recent studies (Faivovich et al., 2005; Hedges and Heinicke, 2007; Hedges et al., 2008; Heinicke et al., 2007; Pramuk, 2006; Pramuk et al., 2001). Toad taxonomy continues to be debated; *Bufo* is used here but some prefer *Peltophryne* as a genus or subgenus.

The recent Global Amphibian Assessment (Stuart et al., 2004) concluded that 84% of West Indian amphibian species are threatened, being listed in the IUCN Redlist categories of Vulnerable, Endangered, and Critically Endangered (IUCN, 2010). This is the largest proportion of threatened species in any major amphibian fauna globally. The relatively small distributions of the species, small amount of remaining forests, and continuing threat from habitat destruction were major factors that led to the designation of such a large proportion of threatened species. Almost

Table 1. Native species of West Indian amphibians, their conservation status, and the most recent year that they were observed in the wild.

Species	Author of taxon	Status[1]	Last year observed[2]
Cuba			
Bufo cataulaciceps	Schwartz, 1959	EN	2009[3]
Bufo empusus	Cope, 1862	VU	2009[3-5,*]
Bufo florentinoi	Moreno and Rivalta, 2007	NA	2009[4-5,*]
Bufo fustiger	Schwartz, 1960	LC	2010[4-5]
Bufo gundlachi	Ruibal, 1959	VU	2009[3-5,*]
Bufo longinasus	Stejneger, 1905	EN	2009[3-5,*]
Bufo peltocephalus	Tschudi, 1838	LC	2010[4-5]
Bufo taladai	Schwartz, 1960	VU	2010[6]
Osteopilus septentrionalis	Duméril and Bibron, 1841	LC	2010[4-7]
Eleutherodactylus acmonis	Schwartz, 1960	EN	2010[6]
Eleutherodactylus adelus	Diaz, Cádiz, and Hedges, 2003	EN	2006[6]
Eleutherodactylus albipes	Barbour and Shreve, 1937	CR	2006[4-6]
Eleutherodactylus atkinsi	Dunn, 1925	LC	2010[6-7]
Eleutherodactylus auriculatus	Cope, 1862	LC	2010[6]
Eleutherodactylus bartonsmithi	Schwartz 1960	CR	2009[4-5]
Eleutherodactylus blairhedgesi	Estrada, Díaz, and Rodríguez, 1997	CR	2009[8]
Eleutherodactylus bresslerae	Schwartz, 1960	CR	2009[4-5]
Eleutherodactylus casparii	Dunn, 1926	EN	2009[4-5]
Eleutherodactylus cubanus	Barbour, 1942	CR	2007[4-6]
Eleutherodactylus cuneatus	Cope, 1862	LC	2010[6]
Eleutherodactylus dimidiatus	Cope, 1862	NT	2010[6]
Eleutherodactylus eileenae	Dunn, 1926	NT	2009[3-5]
Eleutherodactylus emiliae	Dunn, 1926	EN	2007[4-5]
Eleutherodactylus erythroproctus	Schwartz, 1960	NA	2007[4-5]
Eleutherodactylus etheridgei	Schwartz, 1958	EN	2009[6,*]
Eleutherodactylus glamyrus	Estrada and Hedges, 1997	EN	2007[4-6]
Eleutherodactylus goini	Schwartz, 1960	VU	2010[4-5]
Eleutherodactylus greyi	Dunn, 1926	EN	2009[4-5]
Eleutherodactylus guanahacabibes	Estrada and Novo Rodríguez, 1985	EN	2010[4-5]
Eleutherodactylus guantanamera	Hedges, Estrada, and Thomas, 1992	VU	2010[6]
Eleutherodactylus gundlachi	Schmidt, 1920	EN	2010[6]
Eleutherodactylus iberia	Estrada and Hedges, 1996	CR	2010[6]
Eleutherodactylus intermedius	Barbour and Shreve, 1937	EN	2009[4-5]
Eleutherodactylus ionthus	Schwartz, 1960	EN	2010[7]
Eleutherodactylus jaumei	Estrada and Alonso, 1997	CR	2007[4-5]
Eleutherodactylus klinikowskii	Schwartz, 1959	EN	2009[3-6,*]
Eleutherodactylus leberi	Schwartz, 1965	EN	2007[6]
Eleutherodactylus limbatus	Cope, 1862	VU	2010[4-5]
Eleutherodactylus maestrensis	Díaz, Cádiz, and Navarro, 2005	DD	2005[4-5,7]
Eleutherodactylus mariposa	Hedges, Estrada, and Thomas, 1992	CR	2007[3-6]
Eleutherodactylus melacara	Hedges, Estrada, and Thomas, 1992	EN	2010[7]
Eleutherodactylus michaelschmidi	Díaz, Cádiz, and Navarro, 2007	NA	2007[6]
Eleutherodactylus olibrus	Schwartz, 1958	NA	2010[4-5]

Table 1. (Continued.)

Species	Author of taxon	Status[1]	Last year observed[2]
Eleutherodactylus orientalis	Barbour and Shreve, 1937	CR	2010[6]
Eleutherodactylus pezopetrus	Schwartz, 1960	CR	2007[4-6]
Eleutherodactylus pinarensis	Dunn, 1926	EN	2009[3-5,*]
Eleutherodactylus planirostris	Cope, 1862	LC	2010[4-7]
Eleutherodactylus principalis	Estrada and Hedges, 1997	EN	2009[6]
Eleutherodactylus ricordii	Duméril and Bibron, 1841	VU	2009[4-6,*]
Eleutherodactylus riparius	Estrada and Hedges, 1998	LC	2010[6]
Eleutherodactylus rivularis	Díaz, Estrada, and Hedges, 2001	CR	2007[6]
Eleutherodactylus ronaldi	Schwartz, 1960	VU	2010[6]
Eleutherodactylus simulans	Díaz and Fong, 2001	EN	2010[6]
Eleutherodactylus staurometopon	Schwartz, 1960	NA	2008[6]
Eleutherodactylus symingtoni	Schwartz, 1957	CR	2010[6]
Eleutherodactylus tetajulia	Estrada and Hedges, 1996	CR	2010[6]
Eleutherodactylus thomasi	Schwartz, 1959	CR	2009[7,*]
Eleutherodactylus toa	Estrada and Hedges, 1991	EN	2010[6]
Eleutherodactylus tonyi	Estrada and Hedges, 1997	CR	2009[4-5,*]
Eleutherodactylus turquinensis	Barbour and Shreve, 1937	CR	2007[4-6]
Eleutherodactylus varians	Gundlach and Peters in Peters, 1864	VU	2009[3,*]
Eleutherodactylus varleyi	Dunn, 1925	LC	2010[4-5,7]
Eleutherodactylus zeus	Schwartz, 1958	EN	2009[3,6,*]
Eleutherodactylus zugi	Schwartz, 1958	EN	2009[6]
Jamaica			
Osteopilus brunneus	Gosse, 1851	LC	2010[9]
Osteopilus crucialis	Harlan, 1826	EN	2010[9]
Osteopilus marianae	Dunn, 1926	EN	2007[9]
Osteopilus wilderi	Dunn, 1925	EN	2009[10]
Eleutherodactylus alticola	Lynn, 1937	CR	1986[11]
Eleutherodactylus andrewsi	Lynn, 1937	EN	2006[12]
Eleutherodactylus cavernicola	Lynn, 1954	CR	2002[13]
Eleutherodactylus cundalli	Dunn, 1926	VU	2010[9]
Eleutherodactylus fuscus	Lynn and Dent, 1942	CR	1984[11]
Eleutherodactylus glaucoreius	Schwartz and Fowler, 1973	NT	2006[12]
Eleutherodactylus gossei	Dunn, 1926	LC	2009[10]
Eleutherodactylus grabhami	Dunn, 1926	EN	2007[12]
Eleutherodactylus griphus	Crombie, 1986	CR	1985[11]
Eleutherodactylus jamaicensis	Barbour, 1910	EN	1987[11]
Eleutherodactylus junori	Dunn, 1926	CR	1998[11]
Eleutherodactylus luteolus	Gosse, 1851	EN	2009[10]
Eleutherodactylus nubicola	Dunn, 1926	EN	1998[11]
Eleutherodactylus orcutti	Dunn, 1928	CR	1985[11]
Eleutherodactylus pantoni	Dunn, 1926	NT	2009[9-10]
Eleutherodactylus pentasyringos	Schwartz and Fowler, 1973	VU	2007[10-11]
Eleutherodactylus sisyphodemus	Crombie, 1977	CR	1984[11]

Table 1. (Continued.)

Species	Author of taxon	Status[1]	Last year observed[2]
Hispaniola			
Bufo fluviaticus	Schwartz, 1972	CR	1971[14]
Bufo fractus	Schwartz, 1972	EN	1969[14]
Bufo guentheri	Cochran, 1941	VU	2010[15-16]
Hypsiboas heilprini	Noble, 1923	VU	2010[15-16]
Osteopilus pulchrilineatus	Cope, 1869	EN	2010[15-16]
Osteopilus vastus	Cope, 1871	EN	2010[15-16]
Osteopilus dominicensis	Tschudi, 1838	LC	2009[11]
Eleutherodactylus abbotti	Cochran, 1923	LC	2010[15-16]
Eleutherodactylus alcoae	Schwartz, 1971	EN	2008[15-16]
Eleutherodactylus amadeus	Hedges, Thomas, and Franz, 1987	CR	1991[11]
Eleutherodactylus aporostegus	Schwartz, 1965	NA	2006[11,17,*]
Eleutherodactylus apostates	Schwartz, 1973	CR	2005[11,17,*]
Eleutherodactylus armstrongi	Noble and Hassler, 1933	EN	2007[18]
Eleutherodactylus audanti	Cochran, 1934	VU	2009[11,*]
Eleutherodactylus auriculatoides	Noble, 1923	EN	2009[15-16]
Eleutherodactylus bakeri	Cochran, 1935	CR	2006[11,17,*]
Eleutherodactylus bothroboans	Schwartz, 1965	NA	1986[11]
Eleutherodactylus brevirostris	Shreve, 1936	CR	2006[11,17,*]
Eleutherodactylus caribe	Hedges and Thomas, 1992	CR	1991[14,*]
Eleutherodactylus chlorophenax	Schwartz, 1976	CR	1985[11]
Eleutherodactylus corona	Hedges and Thomas, 1992	CR	1991[14,*]
Eleutherodactylus counouspeus	Schwartz, 1964	EN	1991[11]
Eleutherodactylus darlingtoni	Cochran, 1935	CR	1985[11]
Eleutherodactylus diplasius	Schwartz, 1973	NA	2006[11,17]
Eleutherodactylus dolomedes	Hedges and Thomas, 1992	CR	1991[14,*]
Eleutherodactylus eunaster	Schwartz, 1973	CR	2005[11,17,*]
Eleutherodactylus flavescens	Noble, 1923	NT	2010[15-16]
Eleutherodactylus fowleri	Schwartz, 1973	CR	1985[11]
Eleutherodactylus furcyensis	Shreve and Williams, 1963	CR	2009[11,*]
Eleutherodactylus glandulifer	Cochran, 1935	CR	1991[11,*]
Eleutherodactylus glanduliferoides	Shreve, 1936	CR	1985[11]
Eleutherodactylus glaphycompus	Schwartz, 1973	EN	2006[11,17,*]
Eleutherodactylus grahami	Schwartz, 1979	EN	1991[11]
Eleutherodactylus haitianus	Barbour, 1942	EN	2009[15-16]
Eleutherodactylus heminota	Shreve and Williams, 1963	EN	2009[15-16,*]
Eleutherodactylus hypostenor	Schwartz, 1965	EN	1984[11]
Eleutherodactylus inoptatus	Barbour, 1914	LC	2010[15-16]
Eleutherodactylus jugans	Cochran, 1937	CR	2009[11]
Eleutherodactylus lamprotes	Schwartz, 1973	CR	2005[11,17]
Eleutherodactylus leoncei	Shreve and Williams, 1963	CR	2007[18]
Eleutherodactylus limbensis	Lynn, 1958	NA	1953[14]
Eleutherodactylus lucioi	Schwartz, 1980	CR	1979[14]
Eleutherodactylus melatrigonum	Schwartz, 1966	NA	1993[11]
Eleutherodactylus minutus	Noble, 1923	EN	2009[15-16]

Table 1. (Continued.)

Species	Author of taxon	Status[1]	Last year observed[2]
Eleutherodactylus montanus	Schmidt, 1919	EN	2007[18]
Eleutherodactylus nortoni	Schwartz, 1976	CR	2006[11,17,*]
Eleutherodactylus notidodes	Schwartz, 1966	NA	1999[11]
Eleutherodactylus oxyrhynchus	Duméril and Bibron, 1841	CR	1991[11]
Eleutherodactylus parabates	Schwartz, 1964	CR	1996[11]
Eleutherodactylus paralius	Schwartz, 1976	NA	1969[14]
Eleutherodactylus parapelates	Hedges and Thomas, 1987	CR	1984[14,*]
Eleutherodactylus patriciae	Schwartz, 1964 (1965)	EN	2009[15-16]
Eleutherodactylus paulsoni	Schwartz, 1964	CR	1991[11]
Eleutherodactylus pictissimus	Cochran, 1935	VU	2009[15-16,*]
Eleutherodactylus pituinus	Schwartz, 1964	EN	2009[15-16]
Eleutherodactylus poolei	Cochran, 1938	CR	1985[11]
Eleutherodactylus probolaeus	Schwartz, 1965	EN	1985[11]
Eleutherodactylus rhodesi	Schwartz, 1980	CR	1985[11]
Eleutherodactylus rucillensis	Cochran, 1939	NA	1986[11]
Eleutherodactylus rufifemoralis	Noble and Hassler, 1933	CR	1999[15-16]
Eleutherodactylus ruthae	Noble, 1923	EN	1963[14]
Eleutherodactylus schmidti	Noble, 1923	CR	1986[11]
Eleutherodactylus sciagraphus	Schwartz, 1973	CR	1984[11]
Eleutherodactylus semipalmatus	Shreve, 1936	CR	1985[19]
Eleutherodactylus sommeri	Schwartz, 1977	NA	2009[15-16]
Eleutherodactylus thorectes	Hedges, 1988	CR	1991[11,*]
Eleutherodactylus tychathrous	Schwartz, 1965	NA	1986[11]
Eleutherodactylus ventrilineatus	Shreve, 1936	CR	2006[11,17,*]
Eleutherodactylus warreni	Schwartz, 1976	CR	1970[14]
Eleutherodactylus weinlandi	Barbour, 1914	LC	2010[15-16]
Eleutherodactylus wetmorei	Cochran, 1932	VU	2009[11,*]
Leptodactylus albilabris	Günther, 1859	LC	2009[15-16]
Bahamas			
Osteopilus septentrionalis	Duméril and Bibron, 1841	LC	1993[11]
Eleutherodactylus planirostris	Cope, 1862	LC	1993[11]
Eleutherodactylus rogersi	Goin, 1955	NA	1993[11]
Puerto Rico Region			
Bufo lemur	Cope, 1868	CR	2009[20]
Eleutherodactylus antillensis	Reinhardt and Lütken, 1862	LC	2010[20-22]
Eleutherodactylus brittoni	Schmidt, 1920	LC	2010[20-21]
Eleutherodactylus cochranae	Grant, 1932	LC	2010[20-22]
Eleutherodactylus cooki	Grant, 1931	EN	2009[20]
Eleutherodactylus coqui	Thomas, 1966	LC	2010[20-22]
Eleutherodactylus eneidae	Rivero, 1959	CR	1990[11]
Eleutherodactylus gryllus	Schmidt, 1920	EN	2010[20-21]
Eleutherodactylus hedricki	Rivero, 1963	EN	2010[20-21]
Eleutherodactylus jasperi	Drewry and Jones, 1976	CR	1981[23]

Table 1. (Continued.)

Species	Author of taxon	Status[1]	Last year observed[2]
Eleutherodactylus juanariveroi	Rios-López and Thomas, 2007	NA	2010[20]
Eleutherodactylus karlschmidti	Grant, 1931	CR	1988[20]
Eleutherodactylus lentus	Cope, 1862	EN	2010[22]
Eleutherodactylus locustus	Schmidt, 1920	CR	2010[20-21]
Eleutherodactylus monensis	Meerwarth, 1901	VU	2006[21-24]
Eleutherodactylus portoricensis	Schmidt, 1927	EN	2010[20-21]
Eleutherodactylus richmondi	Stejneger, 1904	CR	2010[20-21]
Eleutherodactylus schwartzi	Thomas, 1966	EN	2010[20]
Eleutherodactylus unicolor	Stejneger, 1904	CR	2010[20-21]
Eleutherodactylus wightmanae	Schmidt, 1920	EN	2010[20-21]
Leptodactylus albilabris	Günther, 1859	LC	2010[20-22]
Lesser Antilles			
Allobates chalcopis	Kaiser, Coloma, and Gray, 1994	VU	1992[14]
Eleutherodactylus amplinympha	Kaiser, Green, and Schmid, 1994 (1995)	EN	2008[25]
Eleutherodactylus barlagnei	Lynch, 1965	EN	1993[26]
Eleutherodactylus johnstonei	Barbour, 1914	LC	2010[27]
Eleutherodactylus martinicensis	Tschudi, 1838	NT	2009[11]
Eleutherodactylus pinchoni	Schwartz, 1967	EN	2001[26]
Pristimantis euphronides	Schwartz, 1967	EN	2010[27]
Pristimantis shrevei	Schwartz, 1967	EN	2006[25,28]
Leptodactylus fallax	Muller, 1926	CR	2007[29]
Leptodactylus validus	Garman, 1887	LC	2007[29]
Cayman Islands			
Osteopilus septentrionalis	Duméril and Bibron, 1841	LC	2010[30]
Eleutherodactylus planirostris	Cope, 1862	LC	2010[30]

[1]IUCN Redlist categories: CR (Critically Endangered), DD (Data Deficient), EN (Endangered), LC (Least Concern), NA (Not Assessed), NT (Near Threatened), and VU (Vulnerable). [2]Observations include collection, visual, or vocalization records, and include data and personal communications from: [3]Roberto Alonso, [4]Luis M. Díaz, pers. obs., [5]Antonio Cádiz, [6]Ariel Rodriguez, [7]Ansel Fong, [8]Javier Torres, [9]Susan Koenig, [10]Alejandro Sánchez, [11]S. Blair Hedges, pers. obs., [12]Miguel Nelson, [13]Byron Wilson, [14]Original description or subsequent literature, [15]Sixto Inchaustegui, [16]Marcelino Hernández, [17]Eladio Fernández, [18]Marcos Rodríguez, [19]University of Florida, Museum of Natural History expedition, [20]Alejandro Sánchez, [21]Patricia Burrowes, [22]Renata Platenberg, [23]Richard Thomas, [24]Rafael Joglar, [25]Robert Powell, [26]Breuil (2002), [27]Craig Berg, [28]Robert W. Henderson, [29]Jay D. King, [30]Fred Burton. *See note added in proof.

as confirmation of the process, a recent statistical analysis of factors associated with IUCN threat status, among all amphibians, concluded that species with small geographic ranges were mostly likely to have high threat risk (Sodhi et al., 2008). However, it is the additional factor of declining habitat — even within many so-called protected areas — that is responsible for such a high proportion of threatened species in the West Indies.

The conservation of West Indian amphibians has been addressed in a large number of recent reviews. Most of these have appeared in the journal *Applied Herpetology*, including general reviews (Hedges, 2006a; Wilson et al., 2006) and others focused on specific islands or groups of islands: Antigua, Barbuda, and Redonda (Daltry, 2007), Dominica (Malhotra et al., 2007), the Dutch Windward Islands (Powell, 2006), the French West Indies (Lorvelec et al., 2007), Grenada and the Grenadines (Daudin and de Silva, 2007; Henderson and Berg, 2006), Puerto Rico (Joglar et al., 2007), and the Virgin Islands (Perry and Gerber, 2006; Platenberg and Boulon, 2006). Besides those reviews, one of us (S.B.H.) also has reviewed the West Indian species of amphibians elsewhere (Hedges, 2008), and, with other authors, the Neotropical species of amphibians in general (Bolaños et. al., 2008). In addition, S.B.H. has reviewed conservation issues related to the direct-developing frogs of the New World (Hedges et al., 2008), which comprise 86% of the West Indian amphibian fauna.

This unusual attention has made the West Indies one of the best known regions of the world in terms of knowledge of the conservation status of its amphibian fauna. This does not mean that all of the data needed are in hand, only that the available information has been summarized and the gaps in our knowledge have been identified. For this reason, we will not attempt to duplicate what has been reviewed elsewhere. Instead, we provide a brief overview here of the conservation status of the species, threats to their survival, and recommendations. Most importantly, we include a species census of the West Indian amphibian fauna listing the most recent year that a species has been observed in the wild. This provides an update of similar lists published by one of us (S.B.H.) in previous years (Hedges, 1993, 1999). Such a list can help focus field efforts in tracking species of concern.

Conservation Status of Species

The recent review of the conservation status of amphibians (Stuart et al., 2004; IUCN, 2010) was done in a systematic fashion using established criteria, and was reviewed by herpetologists who conduct research in the West Indies and are familiar with particular species and groups of species. The major review was made in 2004 and some species accounts have since been updated. It is the best available review of the status of species globally. In it, 84% of the total native species in the region (169 species at the time of assessment) were found to be threatened. Of those, 64 were listed as Critically Endangered, 60 as Endangered, and 18 as Vulnerable (table 1). Another six species were considered to be Near Threatened. There is no other region in the world with such a high proportion of threatened species. It is especially worrisome that more than one-third (37%) of the native species of West Indian amphibians were placed in the highest threat category, Critically Endangered. To determine that a species of amphibian, especially a small frog, is actually extinct is difficult because of the complexity and remoteness of the habitat and near-impossibility of examining every possible place where an individual might exist. For this reason, the IUCN designation of “possibly extinct” is appropriate in these cases of critically endangered species that have not been seen in many years and may be extinct.

Since that assessment in 2004, 17 additional new species, including those elevated from subspecies, were added to the list of amphibian species native to the West Indies (table 1). None has yet to be assessed for conservation status under IUCN guidelines. Moreover, any species which has been affected by the elevation of a subspecies must be reassessed because — by definition — the distribution of that species is now smaller.

In addition to listing the conservation status of each native species in table 1, we note the year of the most recent observation of a species in the wild. Unlike highly visible animals such as birds, tropical amphibians tend to be cryptic and it is not unusual for a species to go unnoticed for years or decades, simply because no one has looked for it. Our table reveals this problem, especially in the case of the Bahamas, Hispaniola, and Jamaica. The original species census for the West Indies in 1993 (Hedges, 1993), updated in 1999 (Hedges, 1999) was fairly up-to-date at that time, because the senior author (S.B.H.) and colleagues had conducted extensive field work on many islands during the 1980s and early 1990s. However, field work on Jamaica and Hispaniola by herpetologists has focused more on individual species rather than faunal surveys in the last 15 years. Consequently, some species on those two large islands have not been sought in two decades. Fortunately, recent field work by the junior author (L.M.D.) and colleagues in Cuba has provided an up-to-date census for the species of that island. Likewise, the resident amphibian biologists of Puerto Rico (e.g., Patricia Burrowes, Raphael Joglar, Alejandro Sánchez, and Richard Thomas), have given us the latest information for that island.

While acknowledging biases in these census data, there are nonetheless 49 species that have not been seen in more than 10 years: 8 on Jamaica, 36 on Hispaniola, 3 on Puerto Rico, 1 in the Bahamas (2 others not seen also occur on Cuba so are not counted here), and 1 in the Lesser Antilles. Even more significantly, 31 species have not been seen in more than 20 years: 6 on Jamaica, 22 on Hispaniola, and 3 on Puerto Rico. Of these species there are at least five that apparently have disappeared, because searches have failed to locate them. Three occur on Puerto Rico (*Eleutherodactylus eneidae, E. jasperi*, and *E. karlschmidti*), one (*E. semipalmatus)* occurs on Hispaniola, and one (*E. orcutti*) occurs on Jamaica. Of the remaining species that have not been seen in 10 or 20 years, there may be some that have disappeared as well, but there are insufficient data from searches and surveys to draw any definite conclusions.

Of the five species that are possibly extinct, three (*Eleutherodactylus karlschmidti, E. semipalmatus*, and *E. orcutti*) occur in and around streams. A fourth species, *E. jasperi*, is an obligate bromeliad-dweller, and the fifth species, *E. eneidae*, is poorly known but is arboreal and occurs in cloud and elfin forest. This high proportion of riparian species (only 7% of all native West Indian species are riparian) is consistent with other regions, especially Middle America, where such species show the most declines (Campbell, 1999; McCranie and Wilson, 2002; Savage, 2002; Bolaños et al., 2008).

One of us (S.B.H) has searched extensively — without success — for all five "missing" species in habitats and localities where they once occurred in abundance. In addition, others have searched for *E. karlschmidti* extensively (Joglar et al., 2007), also without success. The current status of the riparian species of Guadeloupe, *E. barlagnei*, is unknown, but concern was expressed that populations were declining in the 1990s (Breuil, 2002). Curiously, other riparian species on Hispaniola (*Hypsiboas heilprini*, *Osteopilus vastus*, *E. schmidti*) and Cuba (*E. cuneatus, E. riparius, E. rivularis*, and *E. turquinensis*) have not disappeared, although none of these species has been monitored at the level of populations and therefore declines in abundance may be taking place.

In November, 2009, S.B.H. conducted a brief survey of amphibians in the Massif de la Selle of Haiti. Some amphibians were found but two critically endangered species, *Eleutherodactylus darlingtoni* and *E. gladuliferoides*, were not encountered at localities where they were found in previous years. Also, in December, 2009, he searched for *Allobates chalcopis* at known localities on Martinique but was unable to find that species. Conditions were somewhat dry on both islands, but it raises some concern and interest in additional, more extensive, surveys.

To summarize the conservation status of the species, most (84%) of the assessed species are threatened and more than two thirds (71%) of the assessed species are either Endangered or Critically Endangered; five of those are possibly extinct. We are concerned that other species that have not been observed in recent years, and which have limited ranges, also may have disappeared.

Threats to Survival

Habitat destruction

Forests originally covered all, or nearly all, of the West Indies before humans arrived. Therefore, as might be expected, amphibians are adapted to forest habitats. Even when a canopy is maintained but only the number of tree species is reduced (e.g., in coffee plantations) the diversity of amphibian species is considerably reduced (CNAP, 2003; Fong, 1999). Forests comprised of only a single species (e.g., of *Pinus* for lumber production), which are sometimes mistakenly counted in tabulations of forest cover, are especially poor habitats for amphibians.

Published values of forest cover for countries often vary because of different ways that the data are collected and analyzed. For example, an area may be scored as forested if as little as 50% or as much as 90% of a cell contains tree canopies. Obviously, if a value of 90% is used, a smaller total area would be scored as forested than if a value of 50% were used. Also, spectral data from satellite imagery may not be interpreted correctly as, for example, forest versus plantation, or primary (original) versus secondary forest. Islands in the West Indies often have many introduced tree species (mango, breadfruit, bamboo, etc.) and these frequently give the impression to a casual observer (and sometimes to compilers of forest cover data), erroneously, that the area is well-forested. Despite this sometimes large margin of error, most surveys have agreed that the West Indies has lost about 90% of its original forests (Hedges, 2006a; Hedges and Woods, 1993; Smith et al., 2005). One small island in the Lesser Antilles, Dominica, has a large amount of original forest but most of the land area, and amphibian species, in the West Indies are in the Greater Antilles and this is where forests have suffered the most. For example, it is doubtful whether Haiti has any remaining primary forest other than in isolated small patches. Entire mountains are essentially denuded, leaving almost no habitat for any organism aside from the decomposers.

Assuming the species-area relationship (MacArthur and Wilson, 1967), a 90% reduction in habitat will lead to a 50% reduction in the number of species. Table 1 indicates that, fortunately, such a prediction has not yet been realized. Why? First, that mathematical prediction does not take into account any other variables, such as the location of the remaining 10% of habitat; in this case it is mostly in upland areas where diversity is highest. Also, it is an equilibrium value, and it is unknown how much time is required to reach equilibrium. The concept of a "lag time" is a realistic assumption and can be seen in Haiti today. In that country, small, isolated patches of forest remain, which barely contribute to any total amount of forest cover. Yet sometimes in those small patches species may persist, temporarily, until even the patches are destroyed. Even if the isolated patches are not destroyed, the quantity or quality of the habitat may be insufficient for many species to persist. Species like this that still exist, but are unlikely to persist, have been referred to as the "living dead" (Wilson, 1992).

The causes of habitat destruction are complex and vary depending on the island, country, population size, and economy. Puerto Rico and Barbados are among the most densely populated areas on Earth. Because of their relatively strong economies, a major pressure on habitat is from urbanization (e.g., roads, buildings, houses, and parking lots). In contrast, destruction of forests in Haiti has been fueled largely by basic subsistence needs, especially energy (charcoal) for cooking food. Initially forests in the West Indies were cut for building materials and agriculture, especially sugar cane, and thus the reasons for habitat destruction have changed with time and levels of forest cover.

Threats other than habitat destruction

Other major threats to West Indian amphibians include a fungal pathogen, introduced predators, and climate change. The fungal pathogen is a chytrid, *Batrachochytrium dendrobatidis*, and it has been a focus of attention for global amphibian declines for the last decade (Collins and Crump, 2009). Recent work has identified how the fungus kills amphibians: by disruption of cutaneous function, including transport of electrolytes (Voyles et al., 2009).

The source region for the fungus is not known with certainty but it is believed to have been introduced to the New World by humans. Mass mortality of amphibians at localities in Panama following the appearance of the fungus has suggested that it is the proximal cause of declines (Lips et al., 2006). However, it is known to coexist with other amphibian faunas without causing declines (Daszak et al., 2005). Recently, two studies have implicated climate change as a factor in declines. In one, it was suggested that warmer climate favored the spread of the disease (Pounds et al., 2006) while in the other it was suggested that climate change alone, without help from the fungus, was responsible for declines through reduction in leaf litter (Whitfield et al., 2007). The relative importance of the chytrid pathogen, climate change, and habitat destruction in amphibian declines continues to be debated (Collins and Crump, 2009).

In the West Indies, the chytrid fungus has been reported in Puerto Rico (Burrowes et al., 2004), Hispaniola (Joglar et al., 2007), Cuba (Díaz et al., 2007), Dominica (Malhotra et al., 2007), Grenada (Henderson and Berg, 2006), and Montserrat (Durrell Wildlife Conservation Trust, unpublished reports). In the broader region of Caribbean islands it has turned up on Tobago as well (Alemu et al., 2008). In Puerto Rico, it seems to be restricted to upland areas and has not yet been found in lowland frog populations (Joglar et al., 2007). The three species of *Eleutherodactylus* in Puerto Rico that have disappeared could not be more different in ecological habits (streamside, bromeliad-dwelling, and arboreal), which makes it difficult to see an obvious link between the fungus and their declines. In a two-year study of *Eleutherodactylus coqui* and *E. portoricensis*, Longo et al. (2009) found that populations were persisting with the chytrid, but drier periods would lead to higher infection levels. In Cuba, the chytrid was discovered in October of 2006 in a dying individual of the endemic toad *Bufo longinasus dunni*. Although there is no current evidence of amphibian declines in Cuba (table 1), populations should be monitored carefully in the future. In Dominica, the chytrid is believed to be responsible for declines in the aquatic-breeding *Leptodactylus fallax*, although other species of frogs (non-aquatic) on the island have apparently not declined (Malhotra et al., 2007).

Over the centuries, humans — including indigenous peoples — have introduced various species of organisms to areas where they were not native. In the West Indies, the Black Rat (*Rattus rattus*) and Norway Rat (*R. norvegicus*) probably first arrived with Columbus in the late 15th Century, followed soon after by cats (*Felis catus*) and dogs (*Canis familiaris*). The Small Indian Mongoose (*Urva auropunctata*) was introduced in the mid-19th Century. All of these mammals, and others, are known to include amphibians in their diet. It is widely believed that at least some species of the native West Indian herpetofauna have become extinct because of such introduced predators (Henderson, 1992).

Because of the broad distribution of these and other introduced predators, there is no place in the West Indies that can be considered "virgin" habitat. For example, *Rattus rattus* is abundant in the uncut elfin forest on El Yunque (Puerto Rico) and is frequently seen climbing around in the canopy at night searching for food, potentially within bromeliads far above the ground. They are so abundant that on one evening an individual rat tripped on a branch, falling from the canopy to the head of the senior author who was recording anuran vocalizations! Also, frogs (*Eleutherodactylus* sp.) have been found in the stomach contents of mongooses from a forested area in eastern Puerto Rico (Viella, 1998). It is not known when these predators successfully colonized the upland forests of Puerto Rico, from the cities and lowlands, but the possibility exists that they may have been a factor in the decline of some species of frogs on that island.

In Cuba, the introduced African catfish (*Clarias gariepinus*) is a potential predator of eggs and tadpoles of those species that breed in water (*Bufo* and *Osteopilus*). The ecological plasticity, reproductive rate, and voracity of these fish, that can survive in a diversity of brackish and freshwater environments (including ditches and streams), make it a serious threat to the native biota. Since 2002, the African catfish has covered the entire island is now present in most rivers and in subterranean waters. Also in Cuba, pigs are a problem for at least one population of toad, *Bufo longinasus longinasus*, at Alturas de Pizarras del Sur, Pinar del Río province (Díaz and Cádiz, 2008), because they are continuously stirring up the margins of the small streams where the toads breed, killing metamorphs, disturbing adults, and clouding the water.

Conclusions and Recommendations

It is easy to review, as we have done here, what is known about the status of West Indian amphibians. But what is needed now are actual data on population levels (Joglar et al., 2007), potential threats (Burrowes et al., 2004; Díaz et al., 2007), and systematic surveys that provide information on the status and ecological health of species or entire faunas. The relationship of the chytrid fungus to amphibian declines continues to be a mystery that needs to be solved. Regardless of the outcome, most species of West Indian amphibians will continue to decline as their habitats decline.

In the West Indies, humans have modified amphibian habitats more than in any other part of the tropics, except for perhaps Madagascar and a few other countries that have similarly low levels of original forest. As the forests disappear, so go the amphibians and other forest-dwelling organisms. This is a fact, and this habitat destruction continues even within most parks and reserves in the Greater Antilles (Puerto Rico being a notable exception). In most cases, laws exist to prevent deforestation but they are often not enforced because of lack of resources.

Aid provided by the governments of developed countries usually is not distributed to developing countries in an innovative or effective manner that would help slow or halt declines of species. Instead, it is the large, non-profit, private organizations, such as The Nature Conservancy and Conservation International, which are in an ideal position to target conservation hot-spots and achieve rapid results. However, despite their active involvement and success in general conservation in the West Indies, both organizations have been slow to respond to the looming extinction crisis in the region.

For example, the most serious crisis for the biodiversity of the West Indies, and one of the most serious of any region in the world, is Haiti. Essentially no original forest remains and the existing biodiversity is literally hanging on by a thread, in small remaining and isolated patches of forest. Dozens of species of amphibians that occur nowhere else, not even in the neighboring Dominican Republic, are threatened with extinction. Haiti has established national parks and they have laws that protect forests and wildlife, but demands on resources within the parks are too great. A modest amount of assistance from private organizations such as The Nature Conservancy and Conservation International, for salaries of park guards and some infrastructure, could make a significant difference in addressing this crisis. The cutting of trees in parks, which is the immediate problem, needs to be stopped immediately. Also, to prepare for the worst, species need to be retrieved for frozen cell cultures (to be used in future whole-animal cloning) and captive breeding before they disappear entirely. For such crises, it is acceptable to focus on the short-term and proximal problems, even if there is no clear long-term solution, because it buys time for species survival.

Also, the conservation value of systematic (biotic) surveys is underappreciated. Systematists are the conservationists of the 21st Century. The great majority of information on the conservation status of amphibians reviewed in the Global Amphibian Assessment by the IUCN (Stuart et al., 2004; IUCN, 2010) was not funded by ecology or conservation grants. It was largely based on work conducted by systematists. Likewise this is true for nearly all West Indian species (table 1): their listing as Endangered, Critically Endangered, etc. is almost entirely based on systematic data (museum specimens and other data from systematists). For years, E.O. Wilson and others have made this same point (Wilson, 1992, 2000, 2004), about the under-appreciation of systematics for conservation, but private conservation agencies in general have been reluctant to fund such systematic surveys. Conservation International's Rapid Assessment Program is a notable exception. More of these programs are needed, and an obvious target in the West Indies would be Haiti.

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Note added in proof

2010 updates for Cuba (observed by L.M. Díaz and A. Cádiz) and Hispaniola (observed by S.B. Hedges) are shown as * in table 1.