Caribherp: exploring the diversity, distribution, and biogeography of Caribbean amphibians and reptiles

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Abstract

Caribherp is a database that functions as a quick identification guide to the 1,077 species of amphibians and reptiles currently known from the Caribbean islands. It has grown over the last two decades, with major changes occurring in the latest version. The site also is updated continuously, as new species are described and taxonomy changes. Species accounts include photos, maps, sound and video files (if available), common names, classification, range area, endemic status, conservation status, and links to articles and sequences. Using filters, users can quickly find species occurring in a geographic region on one of 910 islands, or at a specific location on an island using an integrated coordinate search tool, and download data files for their research. Discovery curves for the region show a continued high rate of species descriptions indicating that the total number of species, described and undescribed, is likely much larger. In contrast, the proportion of threatened amphibian (65%) and reptilian (32%) species in the region is considerably higher than the global average (41% and 21%, respectively), indicating that species will likely be going extinct before they are discovered. The slope (0.27) of the species-area relationship is typical for islands, but it is higher (0.37) when only endemic species are considered, many of which evolved on the islands. Individual species have a median range area of 491 km^2. However, on most islands smaller than ~1,000 km^2, ranges fill the entire island, appearing constrained by island limits. On islands larger than ~1,500 km^2, median range size remains about that size regardless of the size of the island, suggesting an optimal range size.

Keywords: Database, Taxonomy, Evolution, Conservation, Field Guide, West Indies, Bahamas, Greater Antilles, Lesser Antilles, Species-area relationship, Distribution, Range.

Introduction

The interest in the biodiversity of the Caribbean islands is of long standing. Even before Linnaeus erected his system of classification in the mid-18th century, naturalists such as Sloane (1725) were writing about their encounters with amphibians and reptiles of the islands. When Schwartz and Henderson's (1991) volume on the herpetofauna of the West Indies was published, 879 species were known from the Caribbean islands (not the West Indies, but the current broader concept used here). That was a very large number, prompting Ernest Williams (1999) to start an article with the following sentence: "With Schwartz and Henderson's massive 1991 compendium on the West Indian herpetofauna, an epoch primarily devoted to collection and description has come to an end." However, this prediction has not come true. Remarkably, 185 species have been described from the region since then, with the discovery curve not yet showing a plateau and therefore suggesting that our taxonomic knowledge is still incomp-

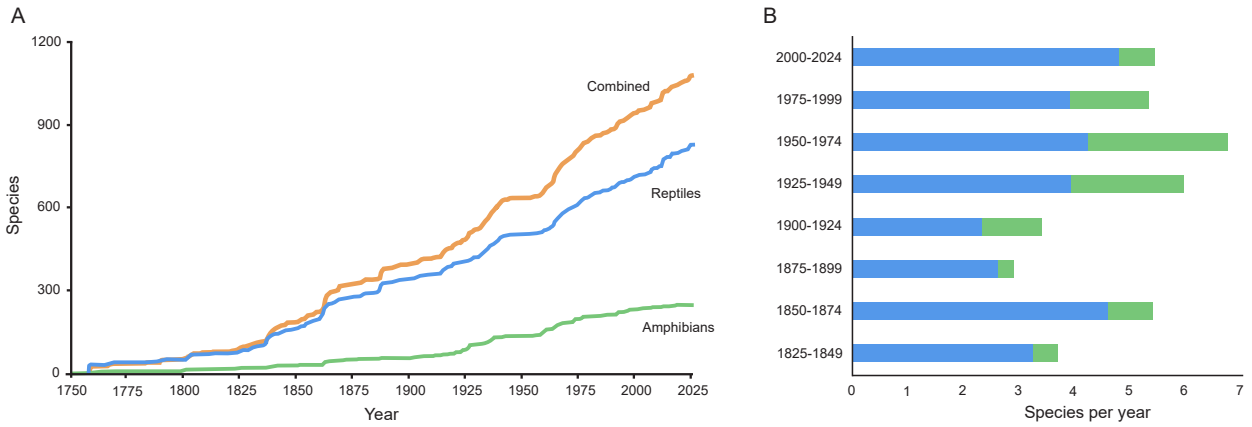

Figure 1. The history of discovery of amphibians and reptiles on Caribbean islands, as defined herein. **(A)** Discovery curves showing cumulative number of valid species through time. **(B)** Average number of valid species described each year, calculated over intervals of 25 years.

lete in 2026 (Fig. 1A). In fact, the annual rate of species description has been remarkably similar over the years, fluctuating between 3–6 species per year (Fig. 1B). At the same time, conservation assessments on the IUCN Redlist (IUCN 2026) continue to find that species on Caribbean islands are among the most threatened in the world, with 65% of amphibians and 32% of reptiles in that category, proportions that are much higher than the global averages of 41% and 21%, respectively (Cox, *et al*. 2022; Luedtke, *et al*. 2023).

Currently, 1,077 total amphibian and reptilian species are known and recognized taxonomically from Caribbean islands. Of those, 829 (77%) are reptiles, 248 (23%) are amphibians, and 908 (84%) are endemic (Table 1). Of those, 28 species have been introduced to other Caribbean islands or elsewhere in the world. Most (63%) of the 133 non-endemic species are on Trinidad and Tobago, islands close to South America and probably connected (at least Trinidad) during the Pleistocene. Nonetheless, many good species evolved during the Pleistocene (2.6 million years ago to 11,700 years ago), a period that encompasses the typical (modal) time-to-speciation (Hedges, *et al*. 2015), including 19 endemic species that are on Trinidad and Tobago. Also, isolation and formation of a species endemic to an island (e.g., Trinidad) could have occurred long before a water barrier was formed. In contrast, endemic species are not likely to have evolved following isolation during the Holocene (< 11,700 years ago) because not enough time has elapsed.

Against this backdrop of a region growing rapidly in numbers of described species, and with many highly threatened, Caribherp was launched by the senior author in 1999, initially as a searchable online checklist following the geographic limits of the "West Indies." A major update (v2) occurred in 2010 with the addition of many photos and maps, and better search and filtering tools. This current version (v3) expands the region of coverage to all Caribbean islands separated from the mainland by at least 20 meters of water depth, thus excluding barrier islands that had recent connections with the mainland (Hedges, *et al*. 2019). Therefore, in addition to the classic islands of the West Indies, the region includes Trinidad and Tobago, the Southern Antilles (north of the Venezuelan mainland), and Caribbean islands belonging to Central American countries (Figs. 2–3). This latest version also has greatly updated search and filtering tools and is mobile-friendly. We herein give an overview of the layout and function of the database and some emerging ecological and evolutionary patterns of the fauna.

Table 1. Number of species of Caribbean amphibians and reptiles with respect to endemic status and Red List status.

	Amphibians	Reptiles	Total species
Endemic Status			
Multi-Island Endemic	34	273	307
Single-Island Endemic	167	406	573
Non-Endemic	31	102	133
Endemic and Introduced	6	22	28
Non-Endemic and Introduced	3	12	15
Introduced from Elsewhere	7	14	21
Red List Status			
Extinct	0	11	11
Critically Endangered	68	115	183
Endangered	65	131	196
Vulnerable	28	42	70
Near Threatened	7	66	73
Least Concern	78	375	453
Not Assessed/Data Deficient	2	89	91
Total	**248**	**829**	**1077**

Layout and function

The unit of Caribherp is the species, which requires some discussion. Hundreds of subspecies have been described for species in the region, but that taxonomic category remains controversial, with dozens of articles expressing different opinions. While a full species will usually maintain reproductive isolation into the future, a subspecies may or may not do so. Some subspecies represent populations that have not diverged sufficiently, genetically, to achieve reproductive isolation and might "merge" with nearby lineages after barriers to dispersal have been removed (Hedges, *et al.* 2015). In that sense, they are no different, evolutionarily, from any isolated population of a species, small or large, young or old, and almost any such isolate can be diagnosed with a genetic or morphological trait. In practice, however, the majority of subspecies that have been carefully examined genetically and morphologically have been elevated to full species—but not all of them (e.g., Köhler, *et al*. 2019; Schools and Hedges 2024). Therefore, neither elevating all of them to full species nor ignoring all of them are viable solutions. We herein advocate the status quo, which is continued study of existing subspecies, but using full species as evolutionary units.

Species accounts, which are the result of a search, are listed in the middle of the viewing area. They consist of textual information, photos, maps, and if available, recordings (frog calls) and videos. The first line of text consists of the genus and species followed by the authors of the species name and the year (placed in parentheses if the species was originally described in a different genus). The second line contains the standardized common name following the guidelines of Hedges *et al*. (2019). The third line is the higher-level taxonomy representing class, order, and family. The fourth line is the primary geographic region where the species occurs. The fifth line is the endemic status, which corresponds to the filter on the left toolbar (see below). The sixth line is the area of the species range, in square kilometers. The seventh line is the IUCN Redlist status, updated annually (although individual species in the Redlist typically are updated by the IUCN every 10–15 years). The eighth line contains links to Google Scholar articles about the species and Genbank DNA sequences for the species.

Photos and maps appear to the right of the account text. Most photos were taken by the senior author

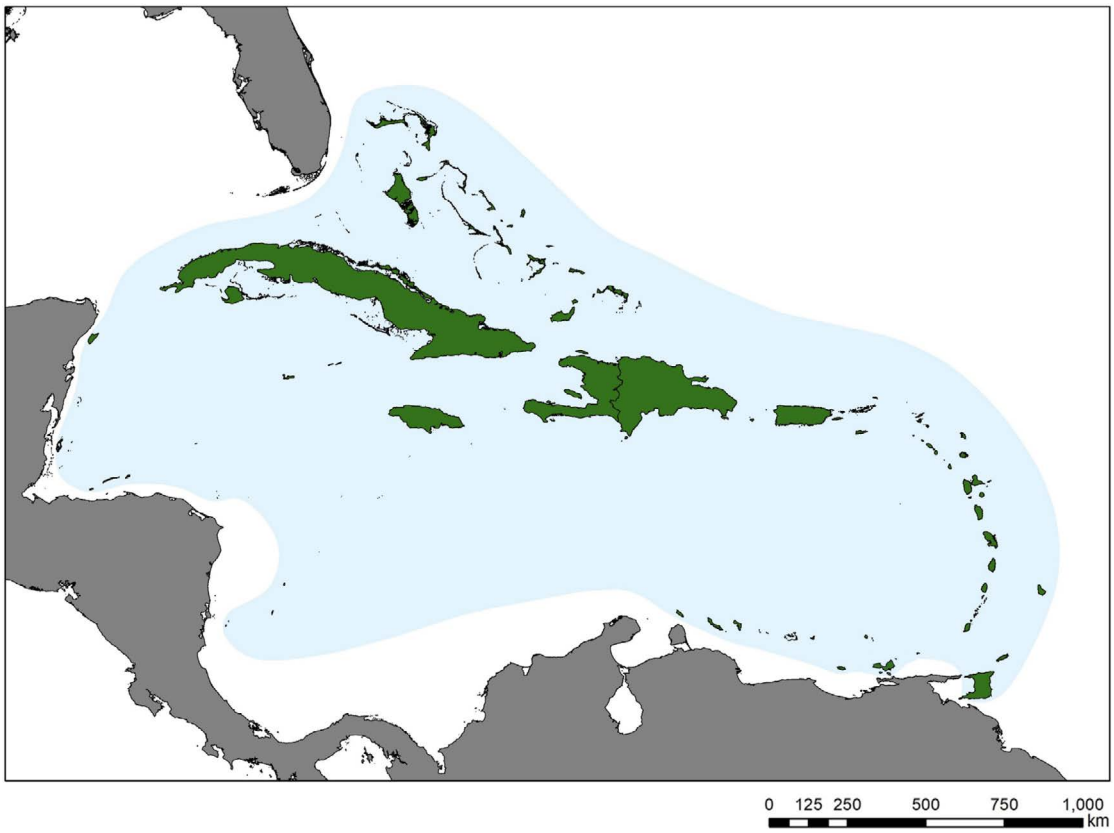

Figure 2. The "Caribbean Islands" biogeographic region. Figure from Hedges *et al*. (2019), with addition of Margarita Island. The pale blue shading includes islands separated from the mainland by at least 20 meters of water depth.

during decades of field work while others were donated (credits listed on the photos and web site). The species distribution map is a polygon integrated with Google maps. Clicking on each map will open Google maps and allow the user to zoom in or out, and select different map settings, including terrain. The species range is the polygon shown in the map (red for native, yellow for introduced), which is smaller than IUCN's extent of occurrence and larger than IUCN's area of occupancy. The area of habitat is the ideal range of a species, closest to reality, and accounts for modeled habitat and elevational constraints (Brooks, *et al*. 2019). Area of habitat is beginning to be incorporated in the IUCN Redlist and will be in Caribherp as well, but for now the "range" is shown, which corresponds to the standard IUCN range and is somewhat larger than the actual area of habitat. The senior author's laboratory produced most IUCN range maps for Caribbean amphibians and reptiles and therefore many in the Redlist are identical to those in Caribherp.

The upper toolbar contains two search bars. The main (lower) one searches globally (all species), and can be useful for finding species not possible through filtering. For example, searching "Reptilia" or "Amphibia" will list all species in each of those groups. Searching "2012" will list all species described in that year. After a global search is conducted, the resulting species can be further filtered using the left-hand toolbar. The upper search bar searches within a geographic region that has already been selected. This might be useful if the user wishes to find (for example) all Hispaniolan species described in 2024.

The left-hand toolbar contains the filters for Caribherp. Geographic filters are at the top and are fine-grained, with country and geographic selections possible. Selecting "All Regions" will show all species in the database (currently 1,077). Alternatively, one might select one of many island groups or one of 910 total islands. For example, after opening the Bahama Islands, the user may select Abaco Islands of the 25 available groups under the Bahama Islands, and choose Mores Island of the 20 possible islands among the Abaco Islands, and find that three

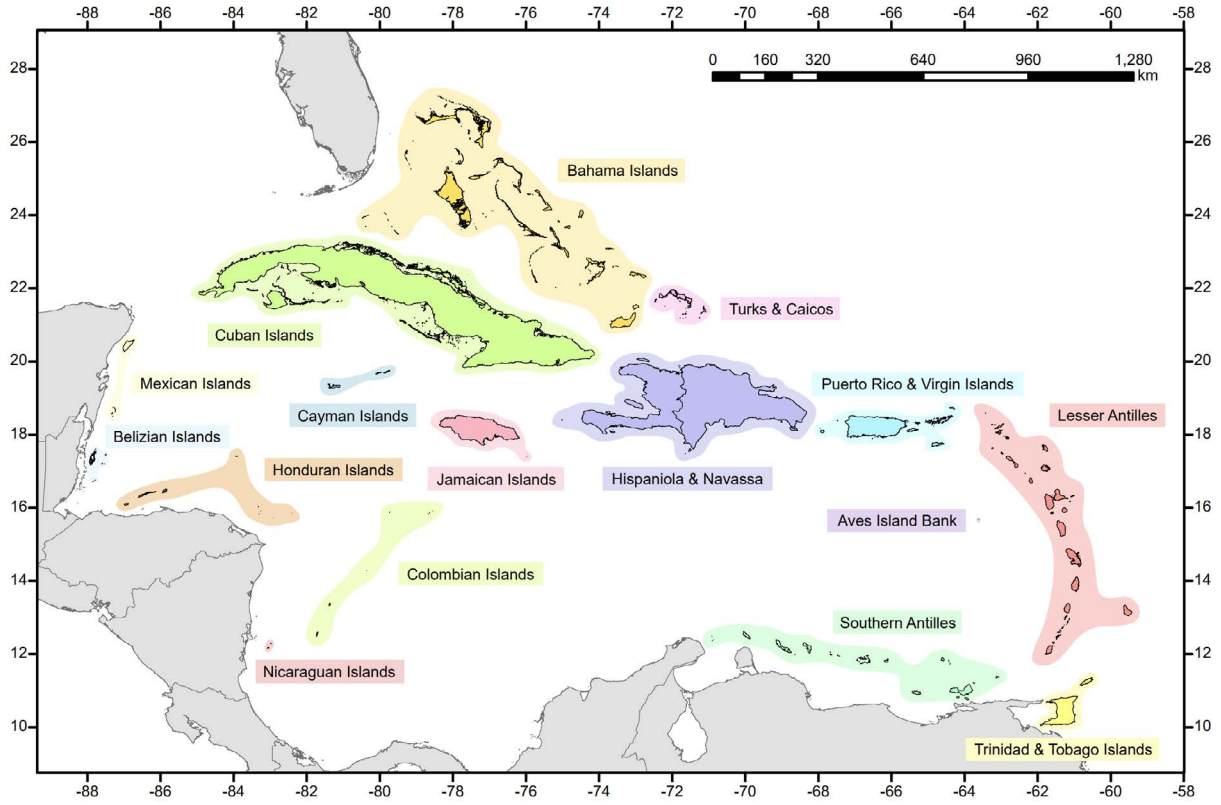

Figure 3. Caribbean islands, labelled according to island groups. Figure from Hedges *et al*. (2019), with addition of Margarita Island.

species are known from that island. If the user wishes to know the species occurring where they are located, the Search-By-Coordinates tool will pull the location from their device and show the species at that spot by inspecting range polygons that overlap with the coordinates (or, any coordinates on Caribbean islands can be entered).

Below the geographic filters are those for Endemic Status and IUCN Red List Status ("endemic" always refers to the region, Caribbean islands, not to a specific island). Island endemic (native) means that the species is endemic to only one island, and that it has not been introduced anywhere. An example would be frog species *Eleutherodactylus bartonsmithi*, known only from a small area in eastern Cuba. Multi-island endemic (native) means that the species is endemic to more than one island, and that it has not been introduced anywhere. An example would be lizard species *Anolis maynardii*, known from Little Cayman and Cayman Brac. Non-endemic (native) means that the species naturally occurs in the Caribbean islands but also occurs naturally outside of the region. An example would be snake species *Helicops angulatus*, native to Trinidad but also occurring in South America. Endemic & introduced means that it is endemic to the Caribbean islands but has been introduced within the islands or elsewhere, or both. An example would be frog species *Eleutherodactylus montserratae*, native to Montserrat but introduced to other islands within the Caribbean. Non-endemic & introduced means that the species is native but not endemic to the Caribbean islands and it has been introduced either among the islands or elsewhere. An example would be lizard species *Gymnophthalmus underwoodi*, native to some Caribbean islands but also occurring in South America and introduced to some islands. Introduced from elsewhere means that the species is neither native nor endemic to the Caribbean islands and has been introduced from outside of the region. An example would be lizard species *Hemidactylus mabouia*, not native to the region but introduced throughout the Caribbean islands.

Researchers can make quick use of data in Caribherp through csv downloads from the top of the main display area. Also, a print button is available for those wishing to export digital (PDF) or paper copies so that they may bring them in the field. In that way, anyone can design their own custom field guide, with photos and maps,

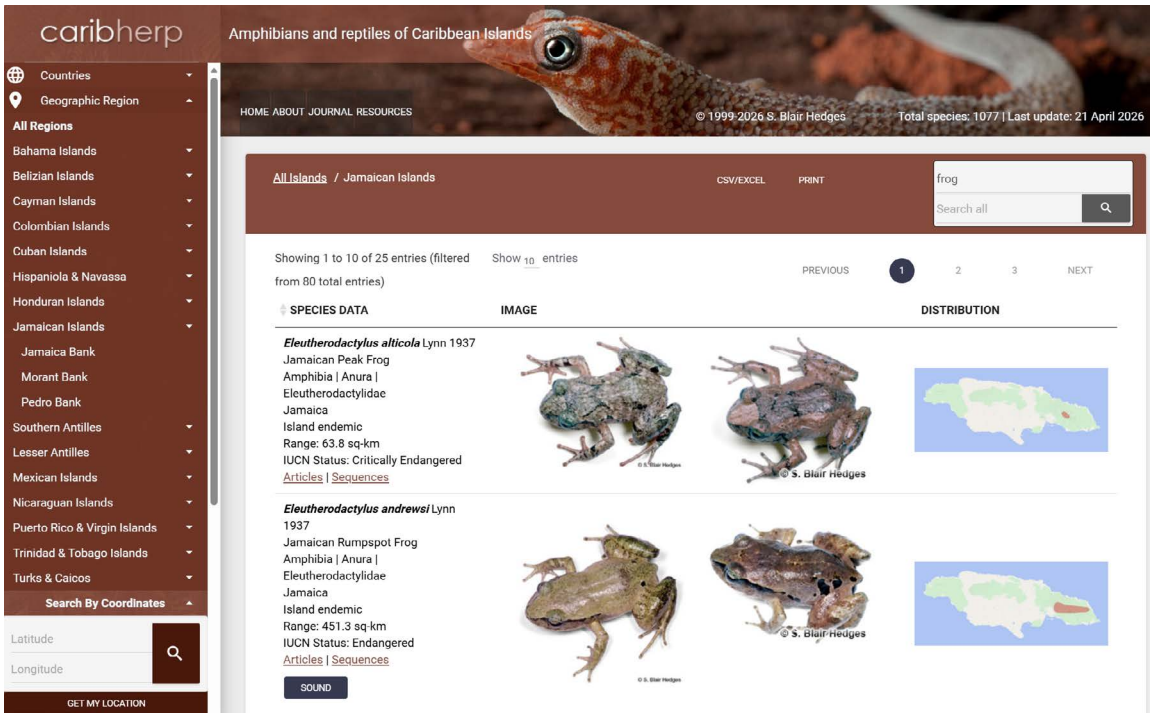

Figure 4. Caribherp layout showing the results of a search of species from Jamaican Islands (yielding 80 entries) followed by a search 'within selected country' for the word "frog" (yielding 25 entries, with two shown here).

of species occurring on an island or in the entire region. A related site, Caribmap (https://www.caribmap.org), contains historical and topographic maps of the region in high resolution, which can be useful in finding old placenames that are absent in modern maps and the internet.

Emergent patterns and processes

In their theory of island biogeography, MacArthur and Wilson (1963) proposed that the stable ("equilibrium") number of species on an island could be predicted as the intersection of the immigration and extinction rate curves. Although that mechanism may explain diversity on some small islands, it fails on many larger islands because of *in situ* speciation (Hedges 1999; Losos and Schluter 2000). In other words, if species are generated within an island, immigration does not apply. For example, all of the 17 island-endemic landfrogs (*Eleutherodactylus*) of Jamaica arose from a single common ancestor that presumably lived on that island and underwent speciation over millions of years (Hedges 1989). Decades of molecular phylogenetic research have shown that all of the four major islands (the Greater Antilles), and some smaller islands, have clades of endemic amphibian and reptilian species that evolved *in situ*. The "island endemic" filter in Caribherp shows that 573 species are endemic to single islands, slightly more than one-half of all species. Immigration was originally responsible for the origin of some of those species, and many of the remaining ones are not endemic to single islands, but *in situ* speciation was nonetheless a major contributor to the diversity of species on Caribbean islands.

Closely related to the mechanisms for generating species diversity on islands is the species-area relationship. Typically, larger islands have more species. MacArthur and Wilson (1967) suggested that this was because of a lower extinction rate on larger islands, resulting from greater habitat diversity on those islands (i.e., more ecological niches for immigrant species to occupy). However, multiple variables can effect the number of species, as discussed by MacArthur and Wilson (1967). For example, islands farther from a source, or less hospitable, or both

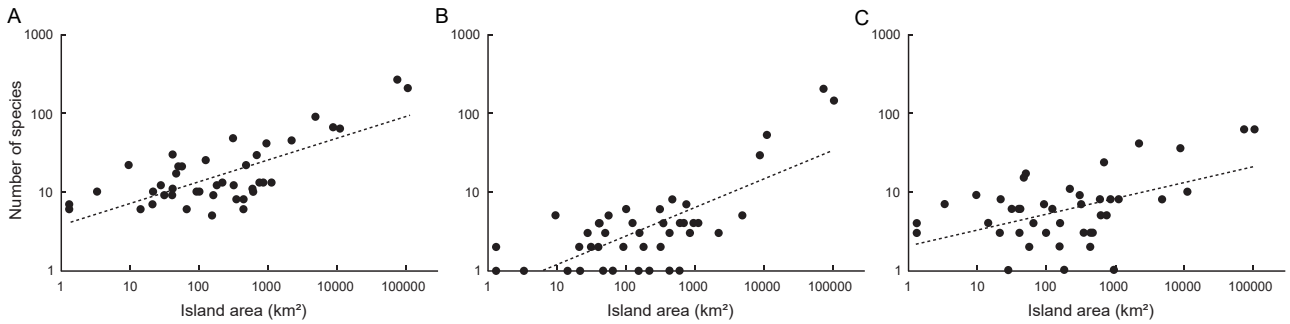

Figure 5. The species-area relationship in native amphibians and reptiles from Caribbean islands. **(A)** Native species (n = 922; z = 0.27; R^2 = 0.83). **(B)** Single island endemic species (n = 546; z = 0.36; R^2 = 0.83). **(C)** Multi-island endemic species (n = 247; z = 0.20; R^2 = 0.64). For each island, only species that are native to that island are counted; species native to some islands are excluded from other islands where they are introduced. A single island < 1km² (Îlet-à-Cochons) is omitted.

will have fewer immigrants. The direction of ocean currents, likewise, will create favorable or unfavorable situations. Similarly, factors conducive or not to geographic isolation, such as the presence or absence of mountain ranges, can affect *in situ* speciation. Therefore, that a meta-analysis of nearly 794 species-area relationship studies resulted in a great variation of outcomes that were difficult to synthesize is not surprising (Drakare, *et al*. 2006).

The current species-area relationship (Fig. 5A) for native species interestingly shows the same canonical 0.27 slope that was proposed by Preston (1962). Early versions of the graph were made when 50% fewer species were known, and constructed with a few islands in a straight line (MacArthur and Wilson 1967), whereas this version shows wide variation typical of this relationship. Considering only single-island endemics, many representing

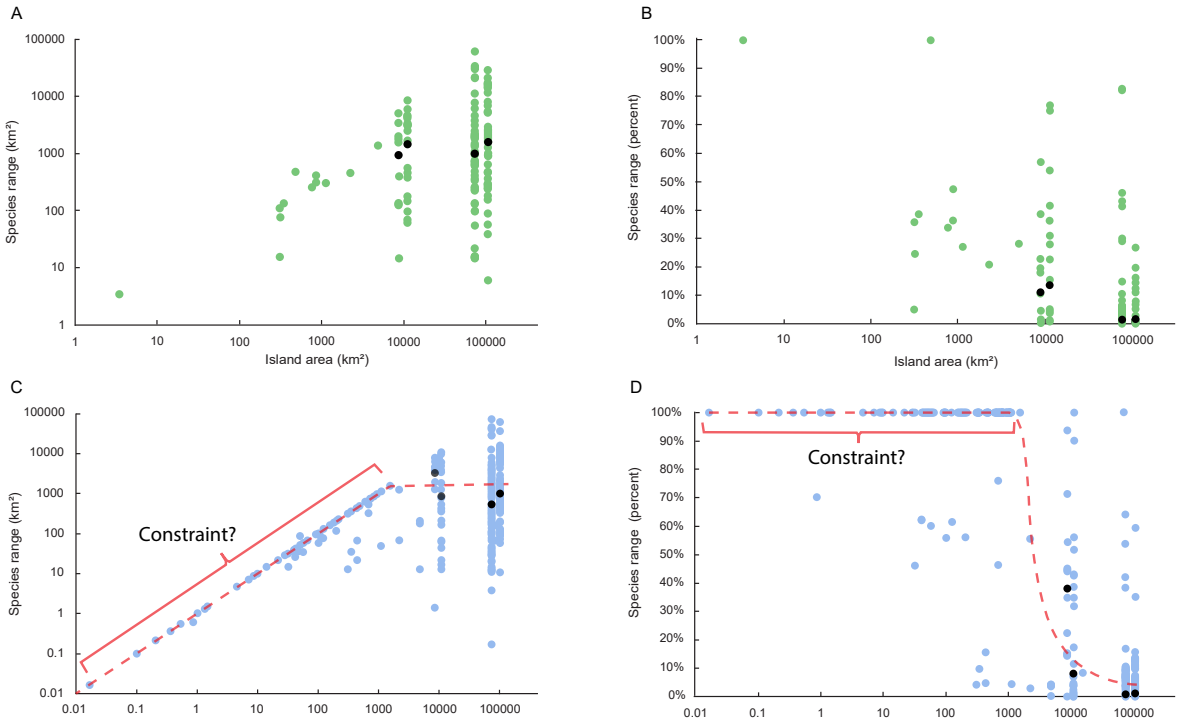

Figure 6. The relationship between range size and island area in amphibians (A–B, green) and reptiles (C–D, blue) from Caribbean islands. Graphs A & C are log10 transformed species range (Y) versus island area (X); black dots are medians. In graphs B & D, species range is shown as a percentage of island area. Red dashed lines in C & D indicate suggested range constraint (see text).

in situ speciation, the slope is much steeper (Fig 5B, 0.36), with multi-island endemics showing a shallower slope (Fig. 5C, 0.20). Focusing on anole lizards, Losos and Schulter (2000) found that *in situ* speciation recorded in phylogenetic trees was not associated with islands smaller than about 3,000 km^2, inferring a lower size limit. Such a limit may be taxon-specific, because two closely related species of frogs (*Eleutherodactylus*) on Guadeloupe (848 km^2) apparently speciated on that island (Myers, *et al*. 2024).

Range size varies considerably among species, but research has shown that species with small ranges tend to occur more frequently in mountains or on islands, are poor dispersers, or evolved recently (Rahbek, *et al*. 2019; Alzate, *et al*. 2025; Sonne, *et al*. 2025). On islands, physical constraints (e.g., coastlines) might keep ranges smaller (Alzate, *et al*. 2025). However, some very large islands in the Caribbean don't seem to constrain the ranges of species and therefore we explored this question with range data in Caribherp.

Species of amphibians and reptiles with the smallest ranges occupy a larger proportion of the island area than species with larger ranges (Fig. 6A, C), which supports the idea of islands constraining a species range. In reptiles, this is even more pronounced than in amphibians, with nearly every species with a range smaller than 1,550 km^2 occupying the entire island on which it occurs (Fig. 6C). However, this relationship changes at that point.

As a result, species ranges of amphibians and reptiles on Jamaica (11,028 km^2) and Puerto Rico (8,752 km^2) have medians of 1,476 km^2 and 947 km^2, respectively, in amphibians and 889 km^2 and 3,350 km^2, respectively, in reptiles, similar to those on the much larger islands of Hispaniola (74,288 km^2) and Cuba (105,231 km^2): 1,001 km^2 and 1,599 km^2, respectively, in amphibians and 542 km^2 and 1,047 km^2, respectively, in reptiles.

In other words, ranges fill on entire islands, to roughly 1,000-1,500 km^2 in island size, at which point they maintain about that median size in islands of increasing sizes, suggesting a typical or optimal range size. This is similar between amphibians and reptiles, suggesting a general pattern deserving of further study.

The Caribbean islands continue to provide a rich source of data for discovering new patterns and testing hypotheses in ecology and evolution. Caribherp database now has additional tools that facilitate such data exploration.

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