



How Many Species Are There in Brazil?

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Abstract: *We produced estimates of the total number of species currently known and the total numbers predicted to occur in Brazil. Lists of species recorded in Brazil were obtained from specialists and the literature. For taxa lacking information on total known species, we produced estimates based on bootstrap resampling from a set of 87 taxa with checklists for Brazil and the world. The estimated proportion of Brazilian species was 9.5% of the world total (95% CI, 8.5 to 11.5%). From this we estimated a known Brazilian biota of 170,000 to 210,000 species. We used a similar procedure to estimate Brazil's total biota—known plus undiscovered. Based on 17 relatively well-known taxa, the average Brazilian share in the world's biota was estimated at 13.1% (CI 10.0 to 17.6%). Accordingly we estimated the country's total biota at 1.8 million species (CI 1.4 to 2.4 million). Given that the Neotropics is the least-studied major region of the world, these figures are still likely to be underestimates and hence may be taken as a lower bound of the actual proportion of the world's species that occur in Brazil. Scientists, policy makers, and citizens will find these numbers useful in appreciating the magnitude of the tasks involved in surveying, describing, and conserving the country's biota. The numbers also bring proposals and priorities into a more realistic perspective.*

¿ Cuantas Especies Hay en Brasil?

Resumen: *Produjimos estimaciones del número total de especies conocidas actualmente y del número total esperado en Brasil. Las listas de especies registradas en Brasil fueron obtenidas de especialistas y de la literatura. Para taxa carentes de información sobre el total de especies conocidas, produjimos estimaciones basadas en muestreos repetidos "bootstrap" a partir de un conjunto de 87 taxa con listados para Brasil y el mundo. La proporción estimada de especies brasileñas fue 9.5% del total mundial (95% IC 8.5 a 11.5%). De aquí estimamos una biota brasileña conocida de 170,000 a 210,000 especies. Usamos un procedimiento similar para estimar la biota total de Brasil - conocida más no descubierta. Con base en 17 taxa relativamente bien conocidos, estimamos que la porción brasileña de la biota mundial es de 13.1% con un intervalo de confianza de 10.0 a 17.6%. Consecuentemente, estimamos la biota total del país en 1.8 millones de especies (IC 1.4 a 2.4 millones). Dado que el Neotrópico es la región menos estudiada del mundo es probable que estas cifras sean subestimaciones y por lo tanto pueden ser considerados el límite inferior de la proporción de especies del mundo que ocurren en Brasil. Estos números son útiles para que científicos, políticos y ciudadanos capten la magnitud del trabajo que implica muestrear, describir y conservar la biota del país y hacer que las propuestas y prioridades tengan una perspectiva más realista.*

Introduction

In this paper we present estimates for the total biological diversity in Brazil (i.e., the numbers of known species

for all taxa, as well as the total numbers [known plus unknown or unrecorded] that are expected to occur in the country). Few all-encompassing estimates are available for any country; therefore, we describe in some detail

our procedures and the rationale for them to facilitate updating as well as criticism or comparison with other national estimates.

These estimates were produced as part of a wide-ranging assessment of the current status of the knowledge and capacity for biodiversity requested by the Brazilian Ministry of the Environment. The evaluation was supported by the United Nations Development Programme (UNDP) and is part of the National Biodiversity Strategy that Brazil, as a party to the Convention on Biological Diversity, has undertaken to produce. Lewinsohn and Prado (2002) present a synthesis of this assessment, and the Ministry of the Environment has produced an updated summary version in English (MMA 2003). The complete updated reports are slated for publication in 2005.

Given the assumptions that are inevitable in such enterprises, many biologists are skeptical about their validity and usefulness. We are aware that these are neither magic numbers nor precise counts and that they should not be used as such. We believe, however, that they have intrinsic usefulness because they furnish an idea of the biological wealth of the country and the challenges inherent in its documentation and conservation.

Methods

We used a two-tiered procedure because each stage had a different goal and sampling universe for estimating unknown components.

Numbers of Described Species

Our first goal was to estimate the number of species known (described or recorded) in Brazil to date. Recent or at least usable catalogs or checklists are available for relatively few taxa: higher vertebrates, some plant families and some algae, lower plants, and invertebrates (e.g., arthropod families). Further information is available from some specialists who have kept informal records on names within certain groups.

Our primary source of information was key specialists on different taxa who were contacted from 1997 to 1999 and asked, among other things, to provide information or estimates of the numerical size of each taxon (preferably as a minimum-maximum range; for details see Lewinsohn & Prado 2002). The chapters contributed to a compilation organized during the planning of the Biota-Fapesp research program were another key source (Joly & Bicudo 1998–1999). Although this program focused on the state of São Paulo, contributors were also asked for Brazilian and world species numbers. The two sources overlapped extensively because in many instances the same specialists were consulted. Estimates were revised in 2003 by consultants who prepared specific sections of the full list to be published by the Ministry of the Environment. We also updated diversity estimates ourselves, whenever we

obtained new information through publications or from unpublished communications with specialists. The resulting set is the most complete compilation of estimates of taxonomic diversity in Brazil currently available.

For taxa lacking an available specialist or someone willing to estimate the number of species described or recorded for the country, we estimated the values from the known ratios of described species known to occur in Brazil. For this, we selected—as comprehensively as possible—all taxa for which specialists refer to catalogs or checklists, both worldwide and for Brazil. At this stage we were not concerned with how many species were still to be described or recorded. We included a taxon if checklists could be assumed to comprise available names and records at comparable levels of thoroughness for Brazil and the world. To avoid many smaller idiosyncratic taxa we set a minimum size of 100 known species in Brazil for a taxon to be included. Taxa were considered at levels from order to phylum, except for arthropods and angiosperms in which larger families were entered individually. In total, 87 taxonomic entities were included (the list is available from the authors on request).

The proportion of known species recorded in Brazil was estimated as the average of the means from each of 10,000 bootstrap samples taken from the selected 87 taxa. Confidence limits were calculated from the distribution of the resulting 10,000 bootstrap means (Manly 1997). Among several variants of this procedure, we conservatively chose the one that produced the widest confidence interval at 95%, which was the bootstrap confidence interval based on Student's *t* distribution calculated from the logarithms of the species numbers. Under the assumption that the selected taxa were a random sample of world taxa, the bootstrap estimate is the expected proportion of described species recorded in Brazil. Applied to taxa not yet cataloged for the country, this yields the number of species one would expect in a current catalog if it were available.

Expected Total Numbers of Species

The estimate of the total number of species in the Brazilian biota, including those as yet undescribed or unrecorded, was based on the taxa that specialists considered to be fairly well inventoried (i.e., in which one does not expect an overall addition exceeding 30% to the species known at present). This expectation can be gauged, for instance, through time series of new species descriptions (Hammond 1994).

Again, we selected those taxa in which we deemed Brazilian coverage to be roughly comparable to worldwide data, judged for instance by recent revisions. This set was clearly much smaller than the first because here comprehensiveness for both geographical entities was of prime concern. For these estimates, we preferred not to use smaller taxa separately so as to avoid pronounced

biogeographic bias, resulting, for instance, from taxa restricted to or almost absent from the Neotropics.

We obtained a set of 17 taxonomic entities (list available on request), to which we applied the same bootstrap procedures described previously. This produced an expected proportion of Brazilian species in the world's biota. We used this ratio to estimate, with appropriate 95% CIs, the total expected size of each taxon in Brazil. For the world's total estimated figures we relied on Hammond (1992) and Hammond et al. (1995), except for later updates for certain taxa.

Results

Table 1 presents numbers of species recorded to date in Brazil. The bootstrapped samples from the set of 87 selected taxa averaged 9.5% of the world's known species (95% CI of 8.5 to 11.5%). These figures, and the following ones, update those in Lewinsohn and Prado (2002). Differences are fairly slight and do not change the general picture. The estimate of known species in Brazil ranged from approximately 170,000 to 210,000. The Brazilian share in the global biota could not be recalculated from this figure because this proportion was itself used to estimate several large groups.

Because arthropods include several very large taxa, they had a strong influence on the total number of supposedly known species. For the four major orders of insects, information was erratic. For Lepidoptera, Brown and Freitas (1999) offer 26,000 as a total for Brazil (17.8% of the world's 146,000 known species); this is quite accurate for butterflies, but a fairly rough guess for many moth families. For Coleoptera, Costa (1999)—based mostly on Blackwelder's (1944–1957) checklist—has approximately 27,600 species recorded in Brazil, of the world's approximately 350,000 species (7.9%, or 8.5% of the 324,000 species total for the families known in Brazil). These figures, however, have a half-century lag in terms of new descriptions, records, and synonymies. No total estimates were available for Hymenoptera and Diptera, although there are checklists or rough estimates for several large families.

Table 2 shows the total number of species expected to exist in Brazil, including those as yet undescribed or unrecorded for the country. These estimates were aggregated as in Hammond et al. (1995), from whom we obtained total estimates of the world's species in major groups. Some of these entities have no formal taxonomic status but are well known and easily recognized.

Our estimates, based on 17 better-known taxonomic entities, averaged 13.1% of the world biota (95% bootstrapped CI of 10.0 to 17.6%). From this proportion, applied to all larger taxa except plants and chordates (Table 2), the total number of species expected to occur in Brazil was estimated to be on the order of 1.8 million (CI of 1.4 to 2.4 million).

Discussion

The estimates we present are contingent on the extrapolation procedure, the accuracy of the primary data, and the underlying assumptions. There is not much to improve on the extrapolation algorithm. In any case, although the figures obtained did vary with alternative procedures, differences in the final estimates were relatively minor.

It is hard to assess the reliability of the primary data—the numbers of species known in various taxa—unless new catalogs and checklists are produced. Such checklists are almost a required starting point for any comprehensive biodiversity assessment, even on a fairly small scale. One may hope that improved data mining and capturing methods will accelerate the production of name lists (for an example of an international initiative with this purpose, see Species 2000 [2004]). Taxonomists are reluctant, however, to sanction “dirty” (unchecked) name lists, and checking published names is inordinately time consuming for any larger taxon.

Extrapolations rest on the assumption that the known portion of a given set represents its unknown portion; otherwise, any rule of proportion is compromised. We cannot ascertain whether existing checklists are a biased subset of all checklists and, if so, to what extent. Therefore we argue that they are the basis for our current best guess, which can be improved if and whenever better information becomes available.

With regard to a potential bias, we can surmise its direction. Given that the world's temperate biota is better known than the tropical biota and the Neotropics are in general considered to be the least-explored major region in the world, we can safely assume that there are relatively more uncollected and/or undescribed species in the Neotropics than elsewhere. Thus, we expect that, especially in large and incompletely surveyed taxa (e.g., bacteria, free-living mites, nematodes, parasitic Hymenoptera), a substantial share of new species will be found in Brazil. This contention is supported by the difference between our two averaged estimates. Among relatively well-known taxa, Brazilian species represent on average 13% of the world's known totals, whereas in the comprehensive set of existing catalogs, Brazilian species average only 8.5% of those in the rest of the world. We therefore consider the overall estimate of 13% as a lower bound for the proportion of the world's biota expected to exist in Brazil.

Current estimates for various taxa in Brazil range from ten to hundreds of thousands of species, and their importance lies in indicating not only the extent of our current knowledge but also the extent of our ignorance. Even the lower estimates, however, lead us to expect that there are roughly seven times more species in Brazil than the number currently recorded. At the current rate of descriptions in or from Brazil (about 1500 species each year, Lewinsohn & Prado 2002), a complete catalog would require at least eight centuries. This is an optimistic figure

Table 1. Number of known species in Brazil and the world estimated by specialists (see Lewinsohn & Prado 2002) or through extrapolation from the average Brazil:world ratio if a recent estimate from specialists was not available.^a

Taxon ^b	Brazil	World ^c
Virus	310–410*	3,600
Monera (Bacteria and Archaea)	800–900	4,300
Fungi—total	13,090–14,510	70,600–72,000
Zygomycota	165	1,056
Ascomycota (including lichenized fungi)	2,740–3,710*	32,267
Basidiomycota	8,900	22,244
Deuteromycota	1,280–1,730*	15,000
Proctotista—total	7,650–10,320	76,100–81,300
Oomycota	133	694
Hyphochytridiomycota	4	24
Labyrinthulomycota	4	42
Chytridiomycota	93	793
Myxomycota s.l. ^d	179	807
“Algae” total	4,180–5,770	37,700–42,900
Bacillariophyta (diatoms)	1,000–1,200	10,000–12,000
Chlorophyta	2,500–3,500	7,800–10,000
Phaeophyta	130–170*	1,500
Rhodophyta	340–580*	4,000–5,000
Chrysophyta	50–100	12,500
Pyrrhophyta	90–130	1,100
Euglenophyta	70–90	800
other Proctotista (“Protozoa”)	3,060–4,140*	36,000
Plantae—total	43,020–49,520	263,800–279,400
Bryophyta s.l. ^e	1,800–3,100	14,000–16,600
Pteridophyta	1,200–1,400	9,000–12,000
“Gymnospermae”	15	806
Magnoliophyta (= Angiospermae)	40,000–45,000	240,000–250,000
Animalia—total	103,780–136,990	1,279,300–1,359,400
“Invertebrates”—total	96,660–128,840	1,218,500–1,298,600
Placozoa	0	1
Porifera	300–400	6,000–7,000
Cnidaria	470	7,000–11,000
Ctenophora	2	90
Platyhelminthes	1,040–2,300*	12,200
Gnathostomulida	0	80–100
“Mesozoa”	0	85
Nemertina	43	1,149
Nematoda	1,280–2,880*	15,000–25,000
Nematomorpha	12	320
Acanthocephala	30–50	1,150
Rotifera	457	2,000
Kinorhyncha	1	150
Priapulida	1	16
Gastrotricha	69	500
Loricifera	0	50
Entoprocta	10	150
Annelida	1,000–1,100	12,000–15,000
Sipuncula	30	150
Echiura	9	130
Pogonophora	1	140
Mollusca	2,400–3,000	70,000–100,000
Tardigrada	67	750–840
Onychophora	4	90
Bryozoa	284	5,500
Brachiopoda	4	355
Phoronida	2	16–18
Chaetognatha	18	125
Hemichordata	7	91
Echinodermata	329	6,000–7,000
“Arthropoda” total	88,790–118,290	1,077,200–1,097,400

(continued)

Table 1. (continued)

Taxon ^b	Brazil	World ^c
Hexapoda (“insects”)	80,750–109,250*	950,000
Myriapoda	400–500	11,000–15,100
Arachnida	5,600–6,500	80,000–93,000
Crustacea	2,040	36,200–39,300
“Chordata”—Total	7,120–7,150	60,800
Urochordata	140–170	3,710
Cephalocordata	2	25
“Pisces” total	3,420	28,460
Agnatha	4	104
Chondrichthyes	155	960
Osteichthyes	3,261	27,400
Amphibia	687	5,504
Reptilia	633	8,163
Aves	1,696	9,900
Mammalia	541	5,023
Total	168,640–212,650	1,697,600–1,798,500

^aCounts based on checklists are presented as single figures. Published estimates or those informed by specialists are presented as ranges whenever they were provided in this form or when sources or specialists diverged. Values from extrapolations are marked with an asterisk (*) and are the products of the world total and bootstrapped 95% confidence limits for the ratio between known number of species in Brazil and the world, obtained from 87 selected taxa (average 9.5%, CI 8.5 to 11.5%). Totals and estimates are rounded to the nearest 10 (Brazil) or 100 (world).

^bTaxonomic divisions according to the consulted specialists, who in general followed Margulis and Schwartz (1998). Some artificial groups that are still customarily used and taxa of uncertain taxonomic status are in quotation marks.

^cAccording to Hammond (1992) and Hammond et al. (1995), except for more recent updates.

^dIncludes Acrasiomycota, Dictyoseliomycota, Plasmodiophoromycota, and Myxomycota strictu sensu.

^eIncludes Hepatophyta, Anthoceroophyta, and Bryophyta strictu sensu.

Table 2. Total numbers of species in major groups (in thousands), known plus unknown or unrecorded, expected to occur in the world (“working figures” as in Hammond et al. 1995:118) and in Brazil (this study).^a

Major group (×1,000)	World		Brazil	
	working figure	average	lower limit	upper limit
Virus	400	52.6	40.1	70.4
Monera	1,000	131.4	100.2	175.9
Fungi	1,500	197.1	150.3	263.9
Protozoa	200	26.3	20.0	35.2
Algae	400	52.6	40.1	70.4
Plantae ^b	320	51.5	48.5	54.5
Nematoda	400	52.6	40.1	70.4
Crustacea	150	19.7	15.0	26.4
Arachnida	750	98.5	75.2	132.0
Insects	8,000	1,051.0	801.8	1,407.6
Mollusca	200	26.3	20.0	35.2
Chordata ^c	50	7.9	7.2	8.8
others	250	32.8	25.1	44.0
total	13,620	1,800.3	1,383.6	2,394.7

^aThe species numbers of 17 relatively well-known taxa correspond to 13.1% of the world biota on average (95% bootstrapped confidence interval 10.0 to 17.6%). Hence, Brazilian estimates were calculated as the products of the world estimates by this average ratio and their confidence intervals.

^bEstimates for Brazil are from Shepherd (2003) based on selected plant families. Estimates calculated with the overall ratio were smaller than the number of known species (Table 1).

^cLower limit calculated for Brazil was lower than the estimated number of known species (Table 1) and was substituted by this value and the average expected number estimated by specialists.

because undescribed species in most taxa are those that are smaller, less conspicuous, and harder to collect and sort (Gaston 1991; Lewinsohn & Prado 2002). In other words, conservation in megadiverse countries must, in a very concrete sense, attempt to avoid losing species that have not even been found.

We perceive several uses for estimates such as those we present here. First, their inexorable vagueness is highly informative; it highlights how far we are from ascertaining even the size of the total sampling and taxonomic enterprise. Improving on these numbers is not a trivial task, and large-scale diversity estimates have been subject to polemics for more than two decades (Erwin 1982; Thomas 1990; Odegaard et al. 2000). Moreover, we have no way of establishing how much of the yet unknown Brazilian biodiversity resides in unknown or scarcely sampled regions and localities, how much is found in little-known habitats (e.g., forest canopy or soil), and how much awaits recognition and description in collection drawers.

Second, the orders of magnitude of our estimates are sufficient to conclude that new strategies are needed for attending to urgent information needs. Without establishing priorities one cannot expect to make effective use of existing knowledge or improve on it substantially in the short term. Lewinsohn and Prado (2002) present a series of such suggested priorities for Brazil. Many scientists do not yet seem fully aware of the extent of this problem. For example, at a time when molecular biology rules,

large-scale bioprospecting proposals are tabled without full recognition of their implications in the field and the taxonomic laboratory.

Finally, national species figures are important to offer citizens, politicians, and other policy makers, giving them a clearer perspective of and a more tangible scale on which to place biodiversity issues. Estimates of their country's biological richness seem to have a striking effect on most people. In presenting and publicizing these numbers, we have no intention of fostering contests among countries; instead, we hope to stimulate a more immediate sense of both wonder and responsibility among Brazilians with regard to our country's incredible biodiversity.

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