

FLORISTICS

An integrated assessment of the vascular plant species of the Americas

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The cataloging of the vascular plants of the Americas has a centuries-long history, but it is only in recent decades that an overview of the entire flora has become possible. We present an integrated assessment of all known native species of vascular plants in the Americas. Twelve regional and national checklists, prepared over the past 25 years and including two large ongoing flora projects, were merged into a single list. Our publicly searchable checklist includes 124,993 species, 6227 genera, and 355 families, which correspond to 33% of the 383,671 vascular plant species known worldwide. In the past 25 years, the rate at which new species descriptions are added has averaged 744 annually for the Americas, and we can expect the total to reach about 150,000.

“What trees!...all utterly new to us. Bonpland keeps telling me he'll go out of his mind if the wonders don't cease soon.”

—Alexander von Humboldt (1)

Fernández de Oviedo's chronicles (2) from 1526 contain the first European accounts of New World plants; they depict huge trees and include the first reports of tobacco, chili pepper, and corn, soon to become widely used throughout the world. Accounts like Oviedo's inspired thousands of botanists to explore the plant riches of the hemisphere over the next five centuries and to collect over 22 million specimens, now housed in the world's herbaria (3), which provide the foundation for our current knowledge (see supplementary text).

The task of naming and classifying plant species remains daunting because of the exuberance of plant diversity in the tropics and the paucity of comprehensive floristic accounts there. In the 1970s, a new era commenced throughout the Americas, as collecting and documenting plants expanded greatly as an activity for in-country institutions, promoting and strengthening the capacity of both institutions and individuals. Because of the large numbers of plant species and the extensive time needed to complete regional (4, 5) or country floras in a region where land clearing and other human activities were driving extinction rapidly (6), many botanists turned to producing online and printed checklists to provide a better understanding of the plants of individual countries or regions. In the 1990s, a series of country-based plant checklists (7–9) was organized by the Missouri Botanical Garden, followed by other lists produced by institutions throughout the Americas (10–16). These checklists present verifiable listings of species based on the analysis

of herbarium specimens, published literature, and expert knowledge of plant specialists. The task of preparing authoritative checklists often proved more difficult than anticipated, in view of the large amounts of data to be synthesized within them, and some of the projects took a decade or more to complete. Checklists are extensively used as aids to identify plants of an area and are valued by derivative projects such as Red Lists [e.g., (17)] and regional lists [e.g., (18)] and as estimates of the number of threatened species [e.g., (19)]. In some countries, they have become the authoritative resource for scholars and decision-makers [e.g., (20)].

Between 1993 and 2016, plant checklists were completed for Mexico (16), the West Indies (14), and all of South America (7–13, 15). Together with two large ongoing flora projects—Flora of North America north of Mexico (hereafter North America) and Flora Mesoamericana, which published, in part (4, 5), records of the occurrences of most of their plant species—a series of data sets became available, making an initial overview of the plants of the Americas possible. Here we merge these floristic efforts into a single checklist to present an initial account of the native vascular plant species known in the Americas. This combined working list was produced through a compilation process using the Missouri Botanical Garden Tropicos database (21).

The total number of native vascular plants known in the Americas comprises 124,993 species, 6227 genera, and 355 families. This corresponds to 33% of the most recent estimate of 383,671 known vascular plant species worldwide (22). At a continental scale, 51,241 species occur on the North American continent (42,941 endemic) and 82,052 in South America (73,552 endemic), with only 8300 species shared between the two continents. The vascular plant flora of South America is 6%

larger than the 77,100 species recorded for Africa (23), which has an area twice its size. Although China has a surface area of similar size to the United States or Canada, its mostly temperate flora consisting of 30,426 species (24) is 97% larger than the flora of the United States and Canada combined.

Within the Americas, Brazil has the most diverse flora, with 33,161 species, followed by Colombia (23,104) and Mexico (22,969) (Fig. 1 and fig. S1A). The most diverse family is Orchidaceae, with 12,983 species, followed by Asteraceae with 12,043 species and Fabaceae with 7473 (fig. S2A); 24 families have more than 1000 species (figs. S2 and S3A). The largely epiphytic Orchidaceae is the most diverse family in the tropical Andean countries, accounting for 9 to 23% of those countries' floras (Ecuador 23%, Colombia 15%, Peru 11%, Venezuela 10%, Bolivia 9%); it is also the most diverse family in Central America (13%) and the Guianas (9%) and is the second most diverse in Brazil (8%). By contrast, Asteraceae is the most-species-rich family in the mostly temperate Southern Cone (15%), North America (14%), and Mexico (13%); this family is second in diversity in most tropical Andean countries and Central America. Fabaceae is the most diverse family in Brazil (8%) and the second most diverse in Mexico (8%), the Guianas (8%), North America (7%), and Venezuela (6%). In the West Indies, the most diverse family is Rubiaceae (7%), which is well represented in all tropical regions; second in diversity are Orchidaceae and Asteraceae (table S1). Fifty-two families are endemic or near endemic to the Americas, including the nearly endemic Berberidopsidaceae, Bromeliaceae, Cactaceae, Calceolariaceae, Humiriaceae, Mitrastemonaceae, and Rapateaceae, with only one or two species of these families found on other continents (table S2). Bromeliaceae is the largest of these families with 3403 species, 39.5% of which are found in Brazil. Five genera have more than 1000 species in the Americas, including pantropical *Piper* (1804) and *Peperomia* (1133) and neotropical *Epidendrum* (1459 species),

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Fig. 1. Map of the Americas showing 12 geographical areas. The areas represent the 12 data sets used to calculate the plant-data summary. For each area, the total number of species of vascular plants and the number of species restricted to that area (in parentheses) are shown.

Miconia (1110), and *Lepanthes* (1035) (fig. S2B and table S3). The majority of genera (5975) and families (223) are represented by fewer than 100 species (fig. S3).

Seventy percent (87,080) of the species in the Americas are restricted in distribution to one of the countries or regions (Fig. 2A and fig. S4). In the West Indies, 67% of the vascular flora is restricted to that region, whereas only 14% of the flora of the Guianas is endemic there. The temperate North America and Southern Cone also show high percentages of restricted species (69 and 45%, respectively). At the country level, Brazil and Mexico have over half of their flora, 55 and 53%, restricted to their borders (fig. S1A). We find, not surprisingly, that larger areas have more range-restricted species than smaller ones (fig. S1B).

Neighboring countries of the tropical Andes, such as Colombia, Ecuador, and Peru, share a large number of their species (between 6799 and 9226; table S4). The floristic similarity among the 12 areas can be gauged from a nonmetric

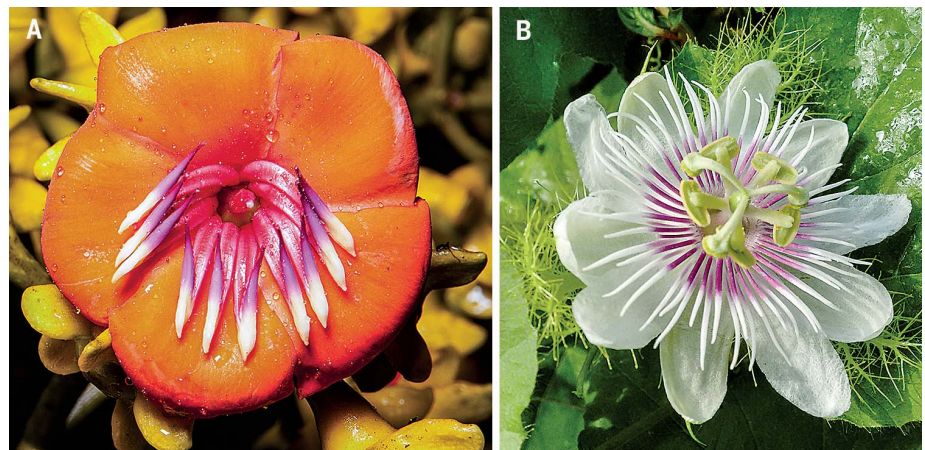


Fig. 2. Contrasting distributions of plant species in the Americas. (A) *Meriania aurata*, one of the 87,080 species with restricted distribution, which only occurs in central Ecuador [Photo credit: L. Jost]. (B) *Passiflora foetida*, one of the 122 species shared among all 12 geographic areas in the Americas [Photo credit: O. Hokche].

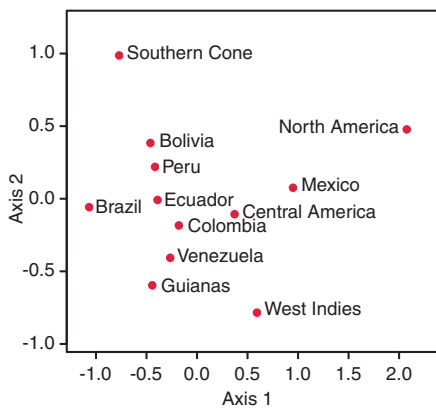


Fig. 3. Floristic similarity among the 12 geographical areas in the Americas. The floristic similarity among the geographic areas represented as a nonmetric multidimensional scaling (NMDS). Distance and placement is indicative of similarity among areas. Axes 1 and 2 show the floristic similarities among regions according to an NMDS ordination based on Sørensen's distances.

multidimensional scaling (Fig. 3). The temperate Southern Cone has the most commonality with Brazil and Bolivia. North America shares, by far, more species with Mexico than with any other area. The West Indies share species with all 11 areas, but their flora is noticeably less similar to that of Peru and the Southern Cone. Of the 124,993 native species in the Americas, only 122 species occur in all of the countries and regions considered here (Fig. 2B and fig. S4).

Our data show that the rate at which plant names are described and accepted for the Americas does not show a tendency to level off. In the past 25 years, between 439 and 1022 (average 744) species have been described each year (Fig. 4). Five to 10 years after the publication of the Brazil, Ecuador, and Peru checklists, the number of known species of plants in those countries increased by 3.6 to 10% (25–28). Brazil is among the four countries globally that continues to yield the greatest number of new species described annually (29). Biologists estimate that as many as 10 to 20% of species could still remain undescribed in tropical American biodiversity hotspots (15, 30, 31). A forecast using linear regression based on the number of new species described between 1990 and 2014 would yield about 152,000 species by 2050 for the Americas (fig. S5).

To date, there has been no previous attempt to catalog the plant diversity of the Americas in its entirety. Because our checklist is compiled from specimen-based data from floras and checklists that cover all sectors of the Americas, it is verifiable and can be readily updated with input from taxonomic specialists. Keeping these listings up-to-date is challenging, given the constant stream of new discoveries and because of taxonomic and nomenclatural changes. Development of computerized databases has helped to manage informa-

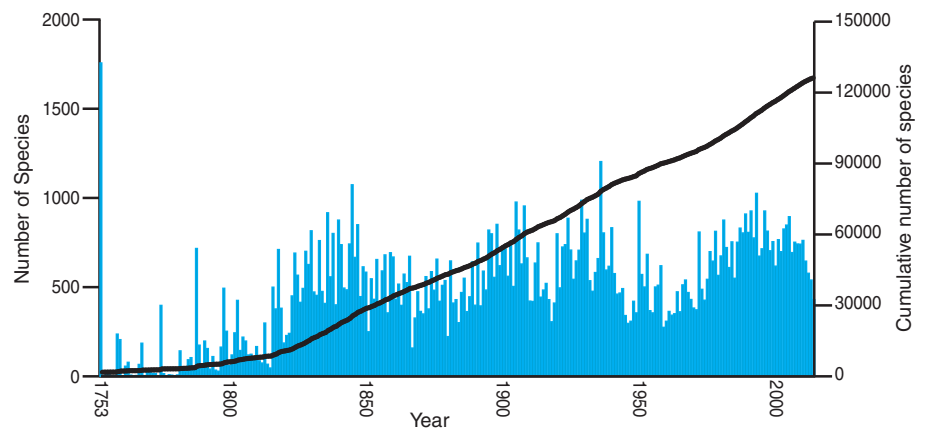


Fig. 4. Species described per year. The number of plant species (basynoms) described per year from 1753 to 2015 for the Americas list (blue bars), and the cumulative number of accepted species (black line).

tion, and the use of molecular-based phylogenies has improved our understanding of taxonomic and biogeographic relationships. Checklist data has proven to be a major source of baseline information for both scientists and governmental decision-makers, and it helps to fulfill major goals of the Global Strategy of Plant Conservation of the United Nation's Convention on Biological Diversity (www.cbd.int/gspc/). Such efforts should assist field-directed and taxonomically oriented research of plants and their distribution, while there is still an opportunity for these to be conducted.

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the supplemental materials, and all of the information is publicly available on a website on the Missouri Botanical Garden database Tropicos at <http://tropicos.org/Project/VPA>.

SUPPLEMENTARY MATERIALS

www.sciencemag.org/content/358/6370/1614/suppl/DC1
Materials and Methods

Supplementary Text
Figs. S1 to S5
Tables S1 to S5
References (32–50)
Data Set S1

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The vascular plants of the Americas

Botanical exploration in the Americas has a history that stretches back for half a millennium, with knowledge assembled in diverse regional floras and lists. Ulloa Ulloa *et al.* present a comprehensive and integrated compilation of all known native New World vascular plant species (see the Perspective by Givnish). This compilation, in a publicly available, searchable database, includes 124,993 species—about one-third of the worldwide total. They further present details of the distribution of species across families and genera, the geographical foci of diversity, and the floristic relationships between regions. The rate of plant species discovery in the Americas averages almost 750 annually, so this valuable resource will continue to grow.

Science, this issue p. 1614; see also p. 1535

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