

The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge

Jan Schipper,^{1,2*} Janice S. Chanson,^{1,2} Federica Chiozza,³ Neil A. Cox,^{1,2} Michael Hoffmann,^{1,2} Vineet Katariya,¹ John Lamoreux,^{1,4} Ana S. L. Rodrigues,^{5,6} Simon N. Stuart,^{1,2} Helen J. Temple,⁷ Jonathan Baillie,⁸ Luigi Boitani,³ Thomas E. Lacher Jr.,^{2,4} Russell A. Mittermeier,² Andrew T. Smith,⁹ Daniel Absolon,¹⁰ John M. Aguiar,^{2,4} Giovanni Amori,¹¹ Noura Bakkour,^{2,12} Ricardo Baldi,^{13,14} Richard J. Berridge,¹⁵ Jon Bielby,^{8,16} Patricia Ann Black,¹⁷ J. Julian Blanc,¹⁸ Thomas M. Brooks,^{2,19,20} James A. Burton,^{21,22} Thomas M. Butynski,^{23,24} Gianluca Catullo,²⁵ Roselle Chapman,²⁶ Zoe Cokeliss,⁸ Ben Collen,⁸ Jim Conroy,²⁷ Justin G. Cooke,²⁸ Gustavo A. B. da Fonseca,^{29,30} Andrew E. Derocher,³¹ Holly T. Dublin,³² J. W. Duckworth,³³ Louise Emmons,³⁴ Richard H. Emslie,³⁵ Marco Festa-Bianchet,³⁶ Matt Foster,² Sabrina Foster,³⁷ David L. Garshelis,³⁸ Cormack Gates,³⁹ Mariano Gimenez-Dixon,⁴⁰ Susana Gonzalez,⁴¹ Jose Fernando Gonzalez-Maya,⁴² Tatjana C. Good,⁴³ Geoffrey Hammerson,⁴⁴ Philip S. Hammond,⁴⁵ David Happold,⁴⁶ Meredith Happold,⁴⁶ John Hare,⁴⁷ Richard B. Harris,⁴⁸ Clare E. Hawkins,^{49,50} Mandy Haywood,⁵¹ Lawrence R. Heaney,⁵² Simon Hedges,³³ Kristofer M. Helgen,³⁴ Craig Hilton-Taylor,⁷ Syed Ainul Hussain,⁵³ Nobuo Ishii,⁵⁴ Thomas A. Jefferson,⁵⁵ Richard K. B. Jenkins,^{56,57} Charlotte H. Johnston,⁹ Mark Keith,⁵⁸ Jonathan Kingdon,⁵⁹ David H. Knox,⁶⁰ Kit M. Kovacs,^{61,62} Penny Langhammer,⁹ Kristin Leus,⁶³ Rebecca Lewison,⁶⁴ Gabriela Lichtenstein,⁶⁵ Lloyd F. Lowry,⁶⁶ Zoe Macavoy,¹⁶ Georgina M. Mace,¹⁶ David P. Mallon,⁶⁷ Monica Masi,²⁵ Meghan W. McKnight,⁶⁸ Rodrigo A. Medellín,⁶⁹ Patricia Medici,^{70,71} Gus Mills,⁷² Patricia D. Moehlman,⁷³ Sanjay Molur,^{74,75} Arturo Mora,⁷⁶ Kristin Nowell,⁷⁷ John F. Oates,⁷⁸ Wanda Olech,⁷⁹ William R. L. Oliver,⁸⁰ Monik Oprea,³⁴ Bruce D. Patterson,⁵² William F. Perrin,⁵⁵ Beth A. Polidoro,¹ Caroline Pollock,⁷ Abigail Powel,⁸¹ Yelizaveta Protas,⁸² Paul Racey,⁵⁶ Jim Ragle,¹ Pavithra Ramani,³⁷ Galen Rathbun,⁸³ Randall R. Reeves,⁸⁴ Stephen B. Reilly,⁵⁵ John E. Reynolds III,⁸⁵ Carlo Rondinini,³ Ruth Grace Rosell-Ambal,⁸⁶ Monica Rulli,²⁵ Anthony B. Rylands,² Simona Savini,²⁵ Cody J. Schank,³⁷ Wes Sechrest,³⁷ Caryn Self-Sullivan,⁸⁷ Alan Shoemaker,⁸⁸ Claudio Sillero-Zubiri,⁸⁹ Naamal De Silva,² David E. Smith,³⁷ Chelmala Srinivasulu,⁹⁰ Peter J. Stephenson,⁹¹ Nico van Strien,⁹² Bibhab Kumar Talukdar,⁹³ Barbara L. Taylor,⁵⁵ Rob Timmins,⁹⁴ Diego G. Tirira,⁹⁵ Marcelo F. Tognelli,^{96,97} Katerina Tsytulina,⁹⁸ Liza M. Veiga,⁹⁹ Jean-Christophe Vié,¹ Elizabeth A. Williamson,¹⁰⁰ Sarah A. Wyatt,² Yan Xie,¹⁰¹ Bruce E. Young⁴⁴

Knowledge of mammalian diversity is still surprisingly disparate, both regionally and taxonomically. Here, we present a comprehensive assessment of the conservation status and distribution of the world's mammals. Data, compiled by 1700+ experts, cover all 5487 species, including marine mammals. Global macroecological patterns are very different for land and marine species but suggest common mechanisms driving diversity and endemism across systems. Compared with land species, threat levels are higher among marine mammals, driven by different processes (accidental mortality and pollution, rather than habitat loss), and are spatially distinct (peaking in northern oceans, rather than in Southeast Asia). Marine mammals are also disproportionately poorly known. These data are made freely available to support further scientific developments and conservation action.

Mammals play key roles in ecosystems (e.g., grazing, predation, and seed dispersal) and provide important benefits to humans (e.g., food, recreation, and income), yet our understanding of them is still surprisingly patchy (1). An assessment of the conservation status of all known mammals was last undertaken by the International Union for Conservation of Nature (IUCN) in 1996 (2). These IUCN Red List classifications of extinction risk (fig. S1) for mammals have been used in numerous studies, including the identification of

traits associated with high extinction risk (3, 4), and prioritization of species for conservation action (5). However, the 1996 assessment was based on categories and criteria that have now been superseded, and the assessments are officially outdated for about 3300 mammals never assessed since. Previously compiled global distribution maps for terrestrial mammals (6, 7) have been used in a variety of analyses, including recommending global conservation priorities (7–9), and analyzing the coverage of protected areas (10). However, nearly 700 currently recog-

nized species, including marine mammals, were not covered in previously published analyses.

Here, we present the results of the most comprehensive assessment to date of the conservation status and distribution of the world's mammals, covering all 5487 wild species recognized as extant since 1500. This 5-year, IUCN-led collaborative effort of more than 1700 experts in 130 countries compiled detailed information on species' taxonomy, distribution, habitats, and population trends, as well as the threats to, human use of, ecology of, and conservation measures for these species. All data are freely available for consultation and downloading (11).

Diversity. Mammals occupy most of the Earth's habitats. As in previous studies (8, 12), we found that land species (i.e., terrestrial, including volant, and freshwater) have particularly high levels of species richness in the Andes and in Afrotropical regions in Africa, such as the Albertine Rift. We also found high species richness in Asia, most noticeably in the Hengduan mountains of southwestern China, peninsular Malaysia, and Borneo (Fig. 1A). The ranges of many large mammals have recently contracted substantially in tropical Asia (13), so local diversity was once undoubtedly even higher. Overall, the species richness pattern for land mammals is similar to that found for birds and amphibians (12), which suggests that diversity is similarly driven by energy availability and topographic complexity (14, 15).

Marine mammals concentrate in tropical and temperate coastal platforms, as well as in off-shore areas in the Tasman and Caribbean seas, east of Japan and New Zealand and west of Central America, and in the southern Indian Ocean. As with land species, marine richness seems to be associated with primary productivity: Whereas land species' richness peaks toward the equator, marine richness peaks at around 40° N and S (16) (fig. S4), corresponding to belts of high oceanic productivity (17). An interesting exception is the low species richness in the highly productive North Atlantic Ocean (17). Only one species' extinction [Sea Mink, *Neovison macrodon* (18)] and one extirpation [Gray Whale, *Eschrichtius robustus* (19)] are recorded from this region, yet evidence for many local extinctions comes from historical records of species exploitation where they no longer occur (e.g., Harp Seal, *Phoca groenlandica*, in the Baltic Sea (20); Bowhead Whale, *Balaena mysticetus*, off Labrador (21); Walrus, *Odobenus rosmarus*, in Nova Scotia (22)). Past human exploitation may therefore have depleted natural species richness in the North Atlantic—as it probably did with land mammals in Australia (23) and the Caribbean (24).

Phylogenetic diversity is a measure that takes account of phylogenetic relationships (and hence, evolutionary history) between taxa (16, 25) (fig. S3). It is arguably a more relevant currency of diversity and less affected by variations in taxo-

nomic classification than species richness. Species richness (Fig. 1A) and phylogenetic diversity (Fig. 1B) are very closely related for land species ($r^2 = 0.98$) (fig. S5), but less so in the marine environment ($r^2 = 0.73$). Disproportionately high phylogenetic diversity in the southern oceans suggests that either species here are less related than elsewhere, or that current species may in fact be poorly known complexes of multiple species, with new species awaiting discovery (consistent with the poor species knowledge in this area, see below).

The size of land species' ranges varies from a few hundred square meters (Bramble Cay Melomys, *Melomys rubicola*; Australia), to 64.7

million km² (Red Fox, *Vulpes vulpes*; Eurasia and North America). For marine species, ranges vary from 16,500 km² (Vaquita, *Phocoena sinu*; Gulf of California), to 350 million km² (Killer Whale, *Orcinus orca*; all oceans). Despite these extremes, most species have small ranges (fig. S6): Most land taxa occupy areas smaller than the UK, and the range of most marine mammals is smaller than one-fifth of the Indian Ocean (fig. S6).

Among land mammals, restricted-range species (those 25% of species with the smallest ranges) are concentrated on highly diverse islands (e.g., Madagascar, Sri Lanka, and Sulawesi) and tropical mountain systems (e.g., Andes,

Cameroonian, and Ethiopian Highlands) (Fig. 1C). Marine restricted-range species are almost entirely found around continental platforms, particularly in the highly productive waters off the Southern Cone of South America (Fig. 1C) (17). Both land and marine patterns of endemism are thus apparently associated with highly productive areas subject to strong environmental gradients (altitudinal in land; depth in marine).

A different perspective on patterns of species' endemism is obtained by mapping global variation in median range size (Fig. 1D). For land species, there is a strong association between landmass width and median range size: The

¹International Union for Conservation of Nature (IUCN) Species Programme, IUCN, 28 Rue Mauverney, 1196 Gland, Switzerland. ²Center for Applied Biodiversity Science, Conservation International, 2011 Crystal Drive, Arlington, VA 22202, USA. ³Department of Animal and Human Biology, Sapienza Università di Roma, Viale dell'Università 32, 00185 Roma, Italy. ⁴Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA. ⁵Department of Zoology, University of Cambridge, Cambridge, CB2 3EJ, UK. ⁶Environment and Energy Science, Mechanical Engineering Department, Instituto Superior Técnico, Portugal. ⁷IUCN Species Programme, 219c Huntingdon Road, Cambridge, CB3 0DL, UK. ⁸Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, UK. ⁹School of Life Sciences, Arizona State University, Post Office Box 874501, Tempe, AZ 85287, USA. ¹⁰62 Bradford Road, Combe Down, Bath, BA2 5BY, UK. ¹¹CNR-Institute for Ecosystem Studies, Consiglio Nazionale Delle Ricerche, Via A. Borelli, 50, 00161 Rome, Italy. ¹²Department of Environmental Science and Policy, School of International and Public Affairs, Columbia University, 420 West 118th Street, New York, NY 10027, USA. ¹³Centro Nacional Patagónico, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), 9120 Puerto Madryn, Argentina. ¹⁴Patagonian and Andean Steppe Program, Wildlife Conservation Society, Boulevard Brown 2825, 9120 Puerto Madryn, Argentina. ¹⁵Mantella-Conservation.org, 75 Plover Way, London, SE16 7TS, UK. ¹⁶Centre for Population Biology, Imperial College London, Silwood Park, Ascot, Berkshire, SL5 7PY, UK. ¹⁷Facultad de Ciencias Naturales e Instituto Miguel Lillo, Miguel Lillo 205, 4000 Tucumán, Argentina. ¹⁸The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), MIKE—Monitoring the Illegal Killing of Elephants, Post Office Box 47074, Nairobi, 00100, Kenya. ¹⁹World Agroforestry Center (ICRAF), University of the Philippines, Los Baños, Laguna 4031, Philippines. ²⁰University of Tasmania, Hobart, Tasmania 7001, Australia. ²¹Earthwatch Institute (Europe), 256 Banbury Road, Oxford, OX2 7DE, UK. ²²Veterinary Biomedical Sciences, The Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Edinburgh, EH25 9RG, Scotland. ²³Eastern Africa Primate Diversity and Conservation Program, Post Office Box 149, 10400 Nanyuki, Kenya. ²⁴Department of Bioscience and Biotechnology, Drexel University, Philadelphia, PA 19104, USA. ²⁵Istituto di Ecologia Applicata, via Arezzo 29, 00162 Rome, Italy. ²⁶23 High Street, Watlington, Oxfordshire, OX49 5PZ, UK. ²⁷Celtic Environment Ltd, 10 Old Mart Road, Torphins, Banchory, Kincardineshire, AB31 4JG, UK. ²⁸Centre for Ecosystem Management Studies, Mooshof 1a, 79297 Winden, Germany. ²⁹Global Environment Facility, 1818 H Street NW, G 6-602, Washington, DC 20433, USA. ³⁰Department of Zoology, Federal University of Minas Gerais, 31270-901 Belo Horizonte, MG, Brazil. ³¹Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada. ³²IUCN Species Survival Commission, c/o South African National Biodiversity Institute, Centre for Biodiversity Conservation, Private Bag X7, Claremont 7735, Cape Town, South Africa. ³³Wildlife Conservation Society—Asia Programs, Wildlife Conservation Society, Bronx, NY 10460, USA. ³⁴Department of Vertebrate Zoology, Division of Mammals, National Museum of Natural History, Smithsonian In-

stitution, Washington, DC, 20013, USA. ³⁵IUCN SSC (Species Survival Commission), African Rhino Specialist Group, Box 1212, Hilton 3245, South Africa. ³⁶Département de biologie, Université de Sherbrooke, Sherbrooke, Québec J1K 2R1, Canada. ³⁷Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, USA. ³⁸Minnesota Department of Natural Resources, 1201 East Highway 2, Grand Rapids, MN 55744, USA. ³⁹Environmental Science Department, University of Calgary, Calgary, AB T2N 1N4, Canada. ⁴⁰Chemin de la Peroude 2 B, CH-1196 Gland, Switzerland. ⁴¹Genética de la Conservación—IBCE-Facultad de Ciencias, Avenida Italia 3318, Montevideo, 11600, Uruguay. ⁴²ProCAT International, Las Alturas, Coto Brus, Costa Rica. ⁴³Australian Research Council, Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland 4811, Australia. ⁴⁴NatureServe, 1101 Wilson Boulevard, 15th Floor, Arlington, VA 22209, USA. ⁴⁵Sea Mammal Research Unit, Gatty Marine Laboratory, University of St. Andrews, St. Andrews, Fife, KY16 8LB, UK. ⁴⁶Australian National University, Canberra, Australian Capital Territory 0200, Australia. ⁴⁷Wild Camel Protection Foundation, School Farm, Benenden, Kent, TN17 4EU, UK. ⁴⁸Department of Ecosystem and Conservation Sciences, University of Montana, Missoula, MT 59812, USA. ⁴⁹Threatened Species Section, Department of Primary Industries & Water, General Post Office Box 44, Hobart, Tasmania 7001, Australia. ⁵⁰School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania 7001, Australia. ⁵¹The Centre for Science Communication, Natural History Filmmaking, 303 Great King Street, University of Otago, Dunedin, 9054, New Zealand. ⁵²Department of Zoology, Field Museum of Natural History, 1400 South Lake Shore Drive, Chicago, IL 60605, USA. ⁵³Wildlife Institute of India, Post Box 18, Dehra Dun, 248 001, India. ⁵⁴Tokyo Woman's Christian University, 2-6-1 Zempukuiji, Suginami-ku, Tokyo, 167-8585, Japan. ⁵⁵Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration Fisheries, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA. ⁵⁶School of Biological Sciences, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, UK. ⁵⁷Madagasikara Voakajy, Boite Postale 5181, Antananarivo (101), Madagascar. ⁵⁸Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg 2050, South Africa. ⁵⁹Department of Zoology, University of Oxford, The Tinbergen Building, South Parks Road, Oxford, OX1 3PS, UK. ⁶⁰Conservation International, Private Bag X7, 7735, Claremont, South Africa. ⁶¹Norwegian Polar Institute, 9296 Tromsø, Norway. ⁶²The University Centre in Svalbard, 9171 Longyearbyen, Norway. ⁶³Copenhagen Zoo and Conservation Breeding Specialist Group—European Regional Office, p/a Anuntiatenstraat 6, 2170 Merksem, Belgium. ⁶⁴Biology Department, San Diego State University, 5500 Campanile Road, San Diego, CA 92182, USA. ⁶⁵Instituto Nacional de Antropología y Pensamiento Latinoamericano, 3 de Febrero 1378 (1426), Buenos Aires, Argentina. ⁶⁶School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, AK 99701, USA. ⁶⁷Department of Biological Sciences, Manchester Metropolitan University, Manchester, M1 5GD, UK. ⁶⁸Nicolás Ruiz No. 100, Barrio de Guadalupe, San Cristóbal de las Casas, CP 29230, Chiapas, México. ⁶⁹Instituto de Ecología, Universidad Nacional Autónoma de México, Apartado Postal 70-275, 04510 Ciudad Universitaria, D.F., México. ⁷⁰Lowland Tapir Conservation Ini-

tative, IPÊ-Instituto de Pesquisas Ecológicas (Institute for Ecological Research), Caixa Postal 47, Nazaré Paulista, CEP 12960-000, São Paulo, Brazil. ⁷¹Durrell Institute of Conservation and Ecology (DICE), University of Kent, Kent, UK. ⁷²The Tony and Lisette Lewis Foundation, 305 Hyde Park Corner, Hyde Park, Sandton 2196, South Africa. ⁷³Wildlife Trust Alliance, 460 West 34th Street, New York, NY 10001, USA. ⁷⁴Zoo Outreach Organisation, Box 1683, 9A, Gopal Nagar, Lal Bahadur Colony Peelamedu, Coimbatore — 641 004 Tamil Nadu, India. ⁷⁵Wildlife Information & Liaison Development Society, 9A Lal Bahadur Colony, Peelamedu, Coimbatore, Tamil Nadu 641004, India. ⁷⁶Species Unit, IUCN South America Regional Office, Calle Quiteño Libre E 15–12 y la Cumbre, Quito, Pichincha, Ecuador. ⁷⁷Cat Action Treasury, Post Office Box 332, Cape Neddick, ME 03902, USA. ⁷⁸Department of Anthropology, Hunter College of the City University of New York, New York, NY 10065, USA. ⁷⁹Warsaw University of Life Sciences, 02-787 Warsaw, Poland. ⁸⁰Philippine Biodiversity Conservation Programme, Fauna & Flora International, 3A Star Pavilion Apartments, 519 Alonso Street, Malate, Manila 1004, Philippines. ⁸¹Victoria University of Wellington, Wellington 6140, New Zealand. ⁸²Department of Ecology, Evolution, and Environmental Biology, Columbia University, 10th Floor Schermerhorn Extension, MC 5557, 1200 Amsterdam Avenue, New York, NY 10027, USA. ⁸³Department of Ornithology and Mammalogy, California Academy of Sciences (San Francisco), Post Office Box 202, Cambria, CA 93428, USA. ⁸⁴Okapi Wildlife Associates, 27 Chandler Lane, Hudson, Quebec, J0P 1H0, Canada. ⁸⁵Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA. ⁸⁶Conservation International (CI)—Philippines, 6 Maalalahanin Street, Teacher's Village, Diliman, Quezon City 1101, Philippines. ⁸⁷Sirenian International, 200 Stonewall Drive, Fredericksburg, VA 22401, USA. ⁸⁸IUCN Tapir Specialist Group, 330 Shoreditch Road, Columbia, SC 29210, USA. ⁸⁹Wildlife Conservation Research Unit, Zoology Department, University of Oxford, Tubney House, Tubney OX13 5QL, UK. ⁹⁰Department of Zoology, University College of Science, Osmania University, Hyderabad, Andhra Pradesh — 500 007, India. ⁹¹WWF International, Avenue du Mont Blanc, CH-1196 Gland, Switzerland. ⁹²International Rhino Foundation, c/o White Oak Conservation Center 581705 White Oak Road, Yulee, FL 32097, USA. ⁹³Aaranyak, 50 Samanwoy Path (Survey), Post Office Beltola, Guwhati — 781 028, Assam, India. ⁹⁴2313 Willard Avenue, Madison, WI 53704, USA. ⁹⁵Fundación Mamíferos y Conservación, Post Office Box 17-23-055, Quito, Ecuador. ⁹⁶ADIIZA (The Argentinean Arid Research Institute) — CONICET, Center for Science & Technology Mendoza, CC 507, 5500 — Mendoza, Argentina. ⁹⁷Department of Environmental Sciences & Policy, University of California, Davis, Davis, CA 95616, USA. ⁹⁸Russian Bat Research Group, Novocherkassky Prospect, 51-84, St. Petersburg 195196, Russia. ⁹⁹Zoology Department, Emílio Goeldi Museum, Avenida Perimetral, 1901, Terra Firme, Belém, Pará, Brazil. ¹⁰⁰Department of Psychology, University of Stirling, Stirling FK9 4LA, Scotland, UK. ¹⁰¹Institute of Zoology, Chinese Academy of Science, Datunlu, Chaoyang District, Beijing, 100101, China.

*To whom correspondence should be addressed. E-mail: jan.schipper@iucn.org

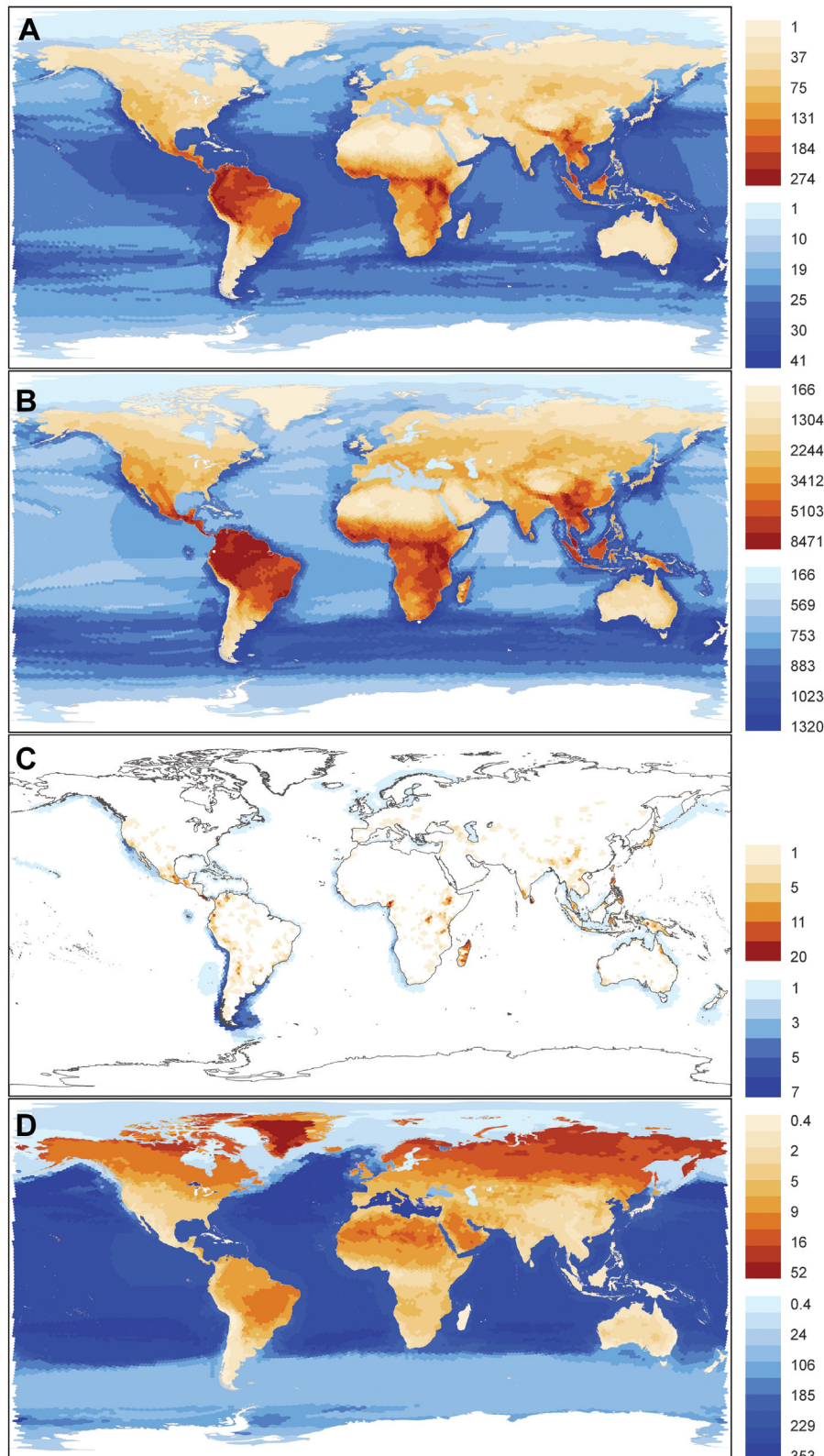


Fig. 1. Global patterns of mammalian diversity, for land (terrestrial and freshwater, brown) and marine (blue) living species, on a hexagonal grid (fig. S2). **(A)** Species richness. **(B)** Phylogenetic diversity (total branch length of the phylogenetic tree representing those species in each cell in millions of years). **(C)** Number of restricted-range species (those 25% species with the smallest ranges). **(D)** Median range size of species in each cell (in million km²).

largest ranges tend to be found across the widest part of each continent, particularly in northern Eurasia, whereas islands (e.g., in Southeast Asia and the Caribbean) and narrow continental areas (e.g., southern North and South America) tend to have narrowly distributed species. Superimposed on this general pattern, ranges also tend to be small in topographically complex areas (e.g., the Rockies, Andes, and Himalayas). These results agree with those for birds, which suggest that range sizes are constrained by the availability of land area within the climatic zones to which species are adapted (14, 26). Among marine species, small median range sizes are found around the continental platforms, which also suggests that steep environmental gradients (here, associated with depth) determine species' distributions. However, the global marine pattern is dominated by a latitudinal effect, with ranges generally declining toward both poles (fig. S7), which may reflect the latitudinal gradient in the overall ocean area. As with previous studies (14, 26), we found no support for the Rapoport rule (27) that the sizes of species' ranges increase with latitude.

Threat. Twenty-five percent ($n = 1139$) of all mammals for which adequate data are available (data sufficient) are threatened with extinction (Table 1). The exact threat level is unknown, as the status of 836 species having insufficient information for evaluation (Data-Deficient species) is undetermined, but is somewhere between 21% (assuming no Data-Deficient species threatened) and 36% (assuming all Data-Deficient species threatened). The conservation status of marine species is of particular concern, with an estimated 36% (range, 23 to 61%) of species threatened.

Critically Endangered species ($n = 188$) (Table 1) face a very high probability of extinction. For 29 of them, it may already be too late: Species like the Baiji (*Lipotes vexillifer*), flagged as "Possibly Extinct," have only a very small chance of still persisting (28). For the 76 species classified as Extinct (since 1500), no reasonable evidence suggests that they still exist. Two Extinct in the Wild species, Scimitar-horned Oryx (*Oryx dammah*) and Père David's Deer (*Elaphurus davidianus*), persist only in captivity.

Species not classified as threatened are not necessarily safe, and indeed, 323 mammals are classified as "Near Threatened" (Table 1). Many species have experienced large range and population declines in the past (e.g., Grey Wolf, *Canis lupus*, and Brown Bear, *Ursus arctos*), which are not accounted for in their current Red List status (13). Moreover, 52% of all species for which population trends are known are declining, including 22% of those classified as of Least Concern. These trends indicate that the overall conservation status of mammals will likely deteriorate further in the near future, unless appropriate conservation actions are put in place. On a positive note, at least 5% of currently threatened species have stable or increasing populations (e.g., European

Bison, *Bison bonasus*, and Black-footed Ferret, *Mustela nigripes*), which indicates that they are recovering from past threats.

Among land mammals, threatened species are concentrated in South and Southeast Asia (Fig. 2A). Among primates, for example, a staggering 79% (range, 76 to 80%) of species in this region are threatened with extinction. Other peaks of threat include the tropical Andes, Cameroon Highlands, Albertine Rift, and Western Ghats in India, all regions combining high species richness (Fig. 1A), high endemism (Fig. 1, B and C), and high human pressure (29). Threatened marine species are concentrated in the North Atlantic, the North Pacific, and Southeast Asia, areas of high endemism (Fig. 1C) and high human impact (30). Low threat levels in the southern hemisphere may reflect history—as these oceans became heavily exploited much more recently—and/or knowledge gaps (see below).

Worldwide, habitat loss and degradation (affecting 40% of species assessed) and harvesting (hunting or gathering for food, medicine, fuel, and materials, which affect 17%) are by far the main threats to mammals (table S2). Yet, the relative importance of different threats varies geographically and taxonomically (Fig. 2, B and C). Among land species, habitat loss is prevalent across the tropics, which coincides with areas of high deforestation in the Americas, Africa, and Asia (Fig. 2B) (31). Harvesting is having devastating effects in Asia, but African and South American species are also affected (Fig. 2C). Harvesting affects large mammals (Cetartiodactyla, Primates, Perissodactyla, Proboscidea, and Carnivora) disproportionately: 90% in Asia, 80% in Africa, and 64% in the Neotropics (compared with 28, 15, and 11% of small mammals, respectively).

Among marine mammals, the dominant threat is accidental mortality (which affects 78% of species), particularly through fisheries by-catch

and vessel strike (table S2). Although coastal areas are the most affected (Fig. 2D), accidental mortality also threatens species in off-shore waters (e.g., from purse seines in the eastern tropical Pacific). Pollution (60% of species) is the second most prevalent threat (Fig. 2E), but this designation includes a diversity of mechanisms, such as chemical contaminants, marine debris, noise, and climate change. Sound pollution (military sonar) has been implicated in mass strandings of cetaceans (32), and climate change is already impacting sea ice-dependent species (e.g., Polar Bear, *Ursus maritimus*, and Harp Seal, *Pagophilus groenlandicus*). Despite progress through international agreements, harvesting remains a major threat for marine mammals (52% of species).

Disease affects relatively few mammals (2%), but it has led to catastrophic declines in some, most dramatically the Tasmanian Devil (*Sarcophilus harrisii*) on account of facial tumor disease (33).

Threat levels are not uniform across mammalian groups (Fig. 3 and table S1). Those with disproportionately high incidence of threatened or extinct species include tapirs (Tapiridae), hippos (Hippopotamidae), tarsiers (Tarsiidae), bears (Ursidae), potoroids (Potoroidae), pigs and hogs (Suidae), and golden moles (Chrysochloridae). Families less threatened than expected include moles (Talpidae), dipodids (Dipodidae), opossums (Didelphidae), and free-tailed bats (Molossidae).

A positive association has been reported between body size and threat among mammals (3, 4), and indeed, we found that the most threatened families are dominated by large species, such as primates and ungulates, whereas the least threatened include small mammals, such as rodents and bats. Larger species tend to have lower population densities, slower life

histories, and larger home ranges and are more likely to be hunted—factors that put them at greater risk (4). For smaller mammals, mostly threatened by habitat loss (34), conservation status is mainly determined by range size and location (4). However, some families of small mammals (e.g., golden moles) are also highly threatened (Fig. 3). Furthermore, although large mammals have a significantly higher fraction of threatened or extinct species ($\chi^2 \approx 0$; $P < 0.0001$), large and small mammals have suffered similar levels of extinction ($\chi^2 = 0.74$; not significant) (34).

Knowledge. Although mammals are among the best-known organisms, they are still being discovered at surprisingly high rates (1). The number of recognized species has increased by 19% since 1992 (fig. S8) and includes 349 newly described species and 512 taxa that were elevated to species level. The spatial pattern of new species description (Fig. 4A) reflects the interaction between the local state of knowledge and taxonomic effort. Peaks in Madagascar and the Amazon result from relatively high, recent taxonomic activity in these poorly known areas, whereas the lack of new species in Africa (particularly in the poorly surveyed Congo Basin) may reflect more limited efforts there.

Newly described mammals are generally poorly known (44% are Data Deficient; 13% for pre-1992 species) and disproportionately threatened [51% (29 to 73%); pre-1992 species: 23% (20 to 33%)]. These factors reinforce the concern that species may be vanishing even before they are known to science.

Newly described species have been named in areas where knowledge has increased in the recent past (Fig. 4A), whereas Data-Deficient species are concentrated in regions in need of future research (Fig. 4B). Most Data-Deficient species on land are in tropical forests (Fig. 4B), which reflects species' richness patterns (Fig. 1A); in regions where these forests are vanishing very rapidly (e.g., Atlantic Forest, West Africa, Borneo) (31), many Data-Deficient species may be dangerously close to extinction.

Marine species are less well studied than land mammals, with 38% Data Deficient (Table 1). Species that breed on land tend to be better understood, but whales, dolphins, porpoises, and sirenians are so difficult to survey that declines that should result in a Vulnerable listing would go undetected at least 70% of the time (35). Marine Data-Deficient species are particularly concentrated along the Antarctic Convergence (Fig. 4B), largely driven by the beaked whales, 19 of which are Data Deficient. A relative absence of Data-Deficient species in the northern Atlantic and Pacific Oceans may reflect higher research effort and expertise—as well as a longer history of exploitation.

Conclusion. Our results paint a bleak picture of the global status of mammals worldwide. We estimate that one in four species is threatened with extinction and that the population of one in

Table 1. Number of species in each IUCN Red List category and threat level for all mammals, and for land and marine species. Categories: EX, Extinct; EW, Extinct in the Wild; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NR, Near Threatened; LC, Least Concern; DD, Data Deficient. Threat level = $[(VU+EN+CR)/(Total - DD)] \times 100$. The range is between $[(VU+EN+CR)/Total] \times 100$ and $[(VU+EN+CR+DD)/Total] \times 100$. NA, not applicable because they are not mapped.

Total and Red List category	Mammal species by habitat		
	All	Land	Marine
Number of species (% of total)			
Total	5487	5282	120
EX	76 (1.4)	NA	NA
EW	2 (0.04)	NA	NA
CR	188 (3.4)	185 (3.5)	3 (2.5)
EN	448 (8.2)	436 (8.3)	12 (10.0)
VU	505 (9.2)	497 (9.4)	12 (10.0)
NT	323 (5.9)	316 (6.0)	7 (5.8)
LC	3109 (56.7)	3071 (58.1)	40 (33.3)
DD	836 (15.2)	777 (14.7)	46 (38.3)
Threat level (%)			
Threat level (range)	25 (21 to 36)	25 (21 to 36)	36 (23 to 61)

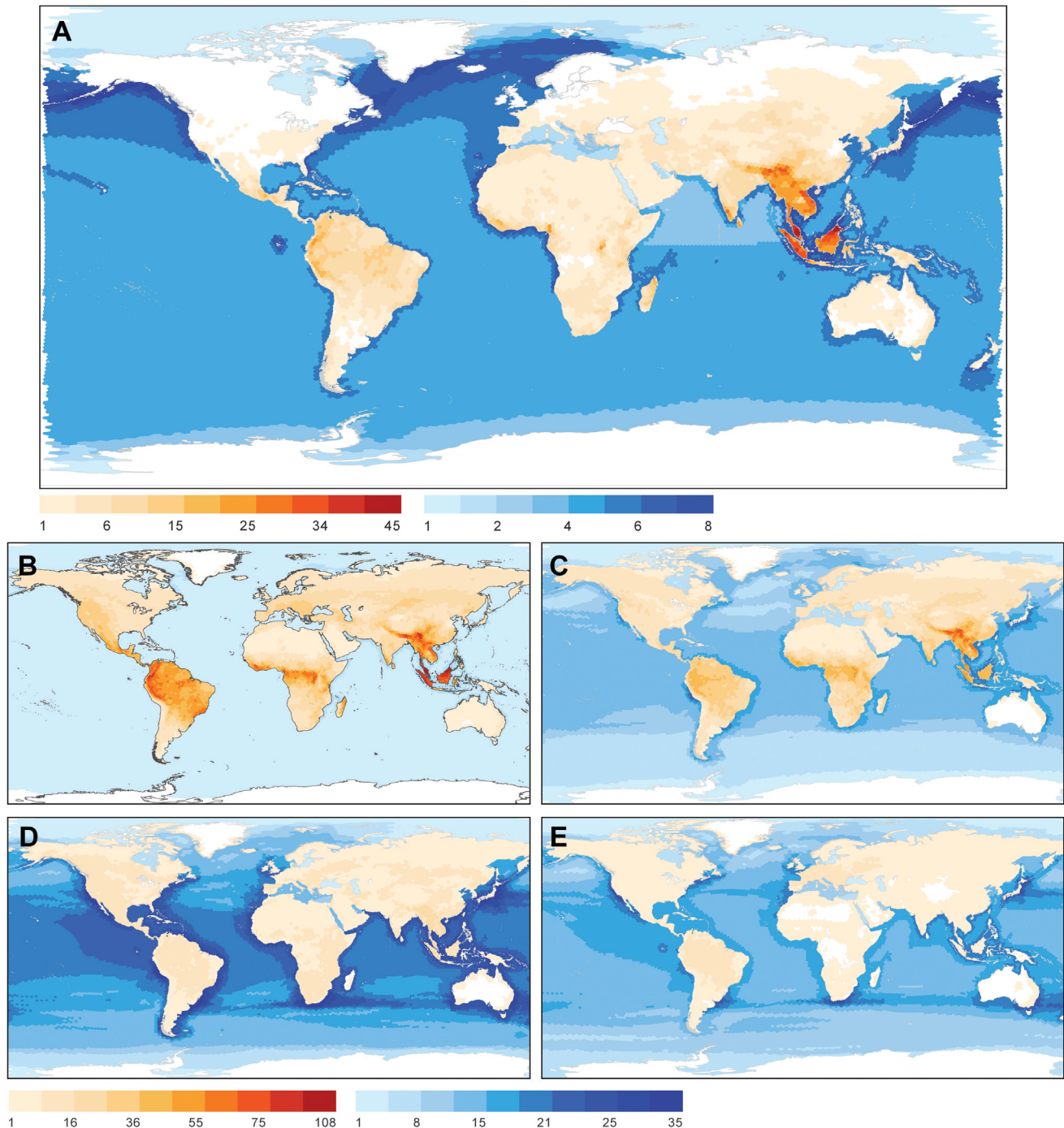


Fig. 2. Global patterns of threat, for land (brown) and marine (blue) mammals. **(A)** Number of globally threatened species (Vulnerable, Endangered or Critically Endangered). Number of species affected by: **(B)** habitat loss; **(C)** harvesting; **(D)** accidental mortality; and **(E)** pollution. Same color scale employed in **(B)**, **(C)**, **(D)** and **(E)** (hence, directly comparable).

two is declining. The situation is particularly serious for land mammals in Asia, through the combined effects of overharvesting and habitat loss, and for marine species, victims of our increasingly intensive use of the oceans. Yet, more than simply reporting on the depressing status of the world's mammals, these Red List data can and should be used to inform strategies for addressing this crisis (36), for example to identify priority species (5) and areas (8, 10) for con-

servation. Further, these data can be used to indicate trends in conservation status over time (37). Despite a general deterioration in the status of mammals, our data also show that species recoveries are possible through targeted conservation efforts.

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Fig. 3. Threat status of each mammalian family in relation to overall threat levels across all mammals (dashed line, 26%). Each family represented by a dot, indicating the percentage of threatened or extinct species, in relation to the total number of data sufficient species in the family. Colored bands indicate significance levels (one-tailed binomial test). Families 1 to 25 have threat levels significantly ($P < 0.01$) different from expected (between brackets, number of threatened or extinct species/number of data sufficient species).

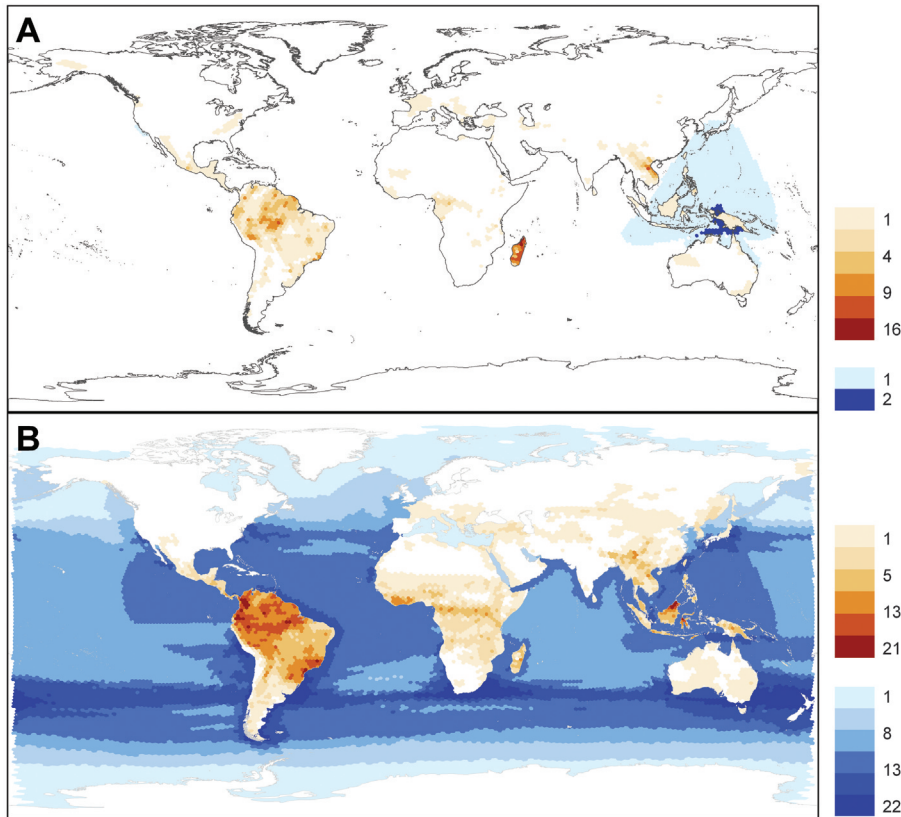
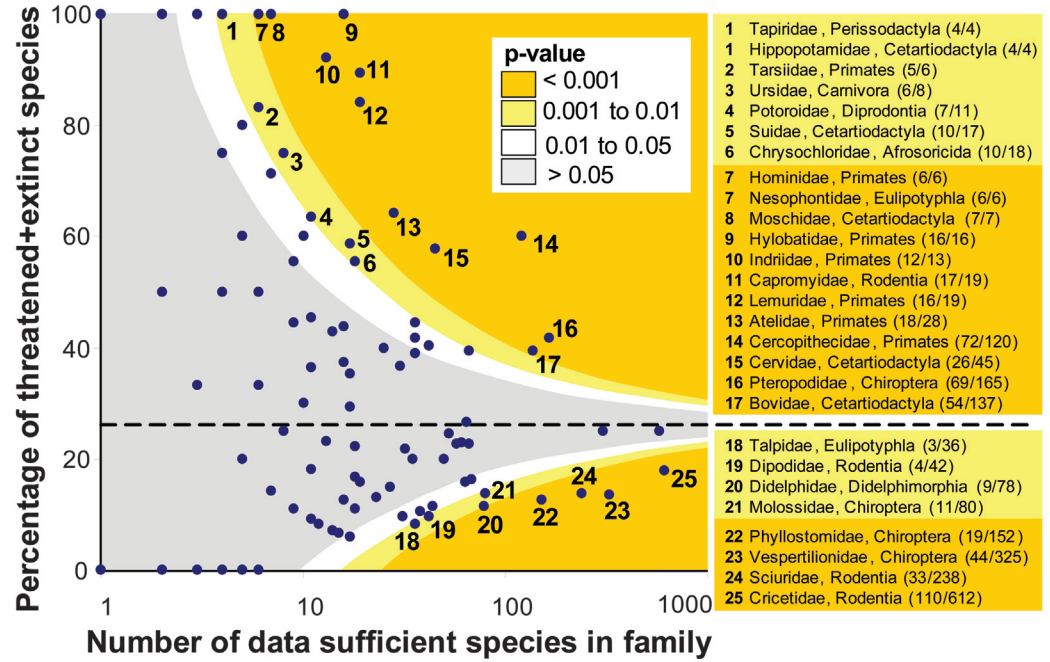


Fig. 4. Global patterns of knowledge, for land (terrestrial and freshwater, brown) and marine (blue) species. (A) Number of species newly described since 1992. (B) Data-Deficient species.

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Supporting Online Material

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Materials and Methods

Figs. S1 to S8

Tables S1 and S2

References

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