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Michael Hoffmann, *et al.*

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The Impact of Conservation on the Status of the World's Vertebrates

Michael Hoffmann,^{1,2*} Craig Hilton-Taylor,³ Ariadne Angulo,^{4,5} Monika Böhm,⁶ Thomas M. Brooks,^{7,8,9} Stuart H. M. Butchart,¹⁰ Kent E. Carpenter,^{2,5,11} Janice Chanson,^{5,12} Ben Collen,⁶ Neil A. Cox,^{5,13} William R. T. Darwall,³ Nicholas K. Dulvy,¹⁴ Lucy R. Harrison,¹⁴ Vineet Katariya,³ Caroline M. Pollock,³ Suhel Quader,¹⁵ Nadia I. Richman,⁶ Ana S. L. Rodrigues,¹⁶ Marcelo F. Tognelli,^{5,13,17} Jean-Christophe Vié,⁵ John M. Aguiar,¹⁸ David J. Allen,³ Gerald R. Allen,¹⁹ Giovanni Amori,²⁰ Natalia B. Ananjeva,²¹ Franco Andreone,²² Paul Andrew,²³ Aida Luz Aquino Ortiz,²⁴ Jonathan E. M. Baillie,²⁵ Ricardo Baldi,^{26,27} Ben D. Bell,²⁸ S. D. Biju,²⁹ Jeremy P. Bird,³⁰ Patricia Black-Decima,³¹ J. Julian Blanc,³² Federico Bolaños,³³ Wilmar Bolívar-G.,³⁴ Ian J. Burfield,¹⁰ James A. Burton,^{35,36} David R. Capper,³⁷ Fernando Castro,³⁸ Gianluca Catullo,³⁹ Rachel D. Cavanagh,⁴⁰ Alan Channing,⁴¹ Ning Labbish Chao,^{42,43,44} Anna M. Chenery,⁴⁵ Federica Chiozza,⁴⁶ Viola Clausnitzer,⁴⁷ Nigel J. Collar,¹⁰ Leah C. Collett,³ Bruce B. Collette,⁴⁸ Claudia F. Cortez Fernandez,⁴⁹ Matthew T. Craig,⁵⁰ Michael J. Crosby,¹⁰ Neil Cumberlidge,⁵¹ Annabelle Cuttelod,³ Andrew E. Derocher,⁵² Arvin C. Diesmos,⁵³ John S. Donaldson,⁵⁴ J. W. Duckworth,⁵⁵ Guy Dutson,⁵⁶ S. K. Dutta,⁵⁷ Richard H. Emslie,⁵⁸ Aljos Farjon,⁵⁹ Sarah Fowler,⁶⁰ Jörg Freyhof,⁶¹ David L. Garshelis,⁶² Justin Gerlach,⁶³ David J. Gower,⁶⁴ Tandora D. Grant,⁶⁵ Geoffrey A. Hammerson,⁶⁶ Richard B. Harris,⁶⁷ Lawrence R. Heaney,⁶⁸ S. Blair Hedges,⁶⁹ Jean-Marc Hero,⁷⁰ Baz Hughes,⁷¹ Syed Ainul Hussain,⁷² Javier Icochea M.,⁷³ Robert F. Inger,⁶⁸ Nobuo Ishii,⁷⁴ Djoko T. Iskandar,⁷⁵ Richard K. B. Jenkins,^{76,77,78} Yoshio Kaneko,⁷⁹ Maurice Kottelat,^{80,81} Kit M. Kovacs,⁸² Sergius L. Kuzmin,⁸³ Enrique La Marca,⁸⁴ John F. Lamoreux,^{5,85} Michael W. N. Lau,⁸⁶ Esteban O. Lavilla,⁸⁷ Kristin Leus,⁸⁸ Rebecca L. Lewison,⁸⁹ Gabriela Lichtenstein,⁹⁰ Suzanne R. Livingstone,⁹¹ Vimoksalehi Lukoschek,^{92,93} David P. Mallon,⁹⁴ Philip J. K. McGowan,⁹⁵ Anna McIvor,⁹⁶ Patricia D. Moehلمان,⁹⁷ Sanjay Molur,⁹⁸ Antonio Muñoz Alonso,⁹⁹ John A. Musick,¹⁰⁰ Kristin Nowell,¹⁰¹ Ronald A. Nussbaum,¹⁰² Wanda Olech,¹⁰³ Nikolay L. Orlov,²¹ Theodore J. Papenfuss,¹⁰⁴ Gabriela Parra-Olea,¹⁰⁵ William F. Perrin,¹⁰⁶ Beth A. Polidoro,^{5,11} Mohammad Pourkazemi,¹⁰⁷ Paul A. Racey,¹⁰⁸ James S. Ragle,⁵ Mala Ram,⁶ Galen Rathbun,¹⁰⁹ Robert P. Reynolds,¹¹⁰ Anders G. J. Rhodin,¹¹¹ Stephen J. Richards,^{112,113} Lily O. Rodríguez,¹¹⁴ Santiago R. Ron,¹¹⁵ Carlo Rondinini,⁴⁶ Anthony B. Rylands,² Yvonne Sadovy de Mitcheson,^{116,117} Jonnell C. Sanciangco,^{5,11} Kate L. Sanders,¹¹⁸ Georgina Santos-Barrera,¹¹⁹ Jan Schipper,¹²⁰ Caryn Self-Sullivan,^{121,122} Yichuan Shi,³ Alan Shoemaker,¹²³ Frederick T. Short,¹²⁴ Claudio Sillero-Zubiri,¹²⁵ Débora L. Silvano,¹²⁶ Kevin G. Smith,³ Andrew T. Smith,¹²⁷ Jos Snoeks,^{128,129} Alison J. Stattersfield,¹⁰ Andrew J. Symes,¹⁰ Andrew B. Taber,¹³⁰ Bibhab K. Talukdar,¹³¹ Helen J. Temple,¹³² Rob Timmins,¹³³ Joseph A. Tobias,¹³⁴ Katerina Tsytulina,¹³⁵ Denis Tweddle,¹³⁶ Carmen Ubeda,¹³⁷ Sarah V. Valenti,⁶⁰ Peter Paul van Dijk,² Liza M. Veiga,^{138,139} Alberto Veloso,¹⁴⁰ David C. Wege,¹⁰ Mark Wilkinson,⁶⁴ Elizabeth A. Williamson,¹⁴¹ Feng Xie,¹⁴² Bruce E. Young,⁷ H. Resit Akçakaya,¹⁴³ Leon Bennun,¹⁰ Tim M. Blackburn,⁶ Luigi Boitani,⁴⁶ Holly T. Dublin,^{144,145} Gustavo A. B. da Fonseca,^{146,147} Claude Gascon,² Thomas E. Lacher Jr.,¹⁸ Georgina M. Mace,¹⁴⁸ Susan A. Mainka,¹⁴⁹ Jeffery A. McNeely,¹⁴⁹ Russell A. Mittermeier,^{2,149} Gordon McGregor Reid,¹⁵⁰ Jon Paul Rodriguez,¹⁵¹ Andrew A. Rosenberg,² Michael J. Samways,¹⁵² Jane Smart,¹⁴⁹ Bruce A. Stein,¹⁵³ Simon N. Stuart^{1,2,154,155}

Using data for 25,780 species categorized on the International Union for Conservation of Nature Red List, we present an assessment of the status of the world's vertebrates. One-fifth of species are classified as Threatened, and we show that this figure is increasing: On average, 52 species of mammals, birds, and amphibians move one category closer to extinction each year. However, this overall pattern conceals the impact of conservation successes, and we show that the rate of deterioration would have been at least one-fifth again as much in the absence of these. Nonetheless, current conservation efforts remain insufficient to offset the main drivers of biodiversity loss in these groups: agricultural expansion, logging, overexploitation, and invasive alien species.

In the past four decades, individual populations of many species have undergone declines and many habitats have suffered losses of

original cover (1, 2) through anthropogenic activity. These losses are manifested in species extinction rates that exceed normal background rates

by two to three orders of magnitude (3), with substantial detrimental societal and economic consequences (4). In response to this crisis, 193 parties to the Convention on Biological Diversity (CBD; adopted 1992) agreed “to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level as a contribution to poverty alleviation and to the benefit of all life on Earth” (5). That the target has not been met was borne out by empirical testing against 31 cross-disciplinary indicators developed within the CBD framework itself (1). However, this does not mean that conservation efforts have been ineffective. Conservation actions have helped to prevent extinctions (6, 7) and improve population trajectories (8), but there has been limited assessment of the overall impact of ongoing efforts in reducing losses in biodiversity (9, 10). Here, we assess the overall status of the world's vertebrates, determine temporal trajectories of extinction risk for three vertebrate classes, and estimate the degree to which conservation actions have reduced biodiversity loss.

Described vertebrates include 5498 mammals, 10,027 birds, 9084 reptiles, 6638 amphibians, and 31,327 fishes (table S1). Vertebrates are found at nearly all elevations and depths, occupy most major habitat types, and display remarkable variation in body size and life history. Although they constitute just 3% of known species, vertebrates play vital roles in ecosystems (11) and have great cultural importance (12). Under the auspices of the International Union for Conservation of Nature (IUCN) Species Survival Commission, we compiled data on the taxonomy, distribution, population trend, major threats, conservation measures, and threat status for 25,780 vertebrate species, including all mammals, birds, amphibians, cartilaginous fishes, and statistically

¹IUCN SSC Species Survival Commission, c/o United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, UK. ²Conservation International, 2011 Crystal Drive, Arlington, VA 22202, USA. ³Species Programme, IUCN, 219c Huntingdon Road, Cambridge CB3 0DL, UK. ⁴IUCN–CI Biodiversity Assessment Unit, c/o P.O. Box 19004, 360 A Bloor Street W., Toronto, Ontario M5S 1X1, Canada. ⁵Species Programme, IUCN, Rue Mauverney 28, 1196, Gland, Switzerland. ⁶Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK. ⁷NatureServe, 1101 Wilson Boulevard, Arlington, VA 22209, USA. ⁸World Agroforestry Center (ICRAF), University of the Philippines Los Baños, Laguna 4031, Philippines. ⁹School of Geography and Environmental Studies, University of Tasmania, Hobart, Tasmania 7001, Australia. ¹⁰BirdLife International, Wellbrook Court, Girton Road, Cambridge CB3 0NA, UK. ¹¹Department of Biological Sciences, Old Dominion University, Norfolk, VA 23529, USA. ¹²IUCN–CI Biodiversity Assessment Unit, c/o 130 Weatherall Road, Cheltenham 3192, Victoria, Australia. ¹³IUCN–CI Biodiversity Assessment Unit, Conservation International, 2011 Crystal Drive Ste 500, Arlington, VA 22202, USA. ¹⁴IUCN Shark Specialist Group, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada. ¹⁵National Centre for Biological Sciences, Tata Institute of Fundamental Research, GKV Campus, Bellary Road, Bangalore 560 065, India. ¹⁶Centre d'Ecologie Fonctionnelle et Evolutive, CNRS UMR5175, 1919 Route de Mende, 34293 Montpellier,

- France. ¹⁷ADIZA-CONICET, CCT-Mendoza, CC 507, 5500 Mendoza, Argentina. ¹⁸Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA. ¹⁹Western Australian Museum, Locked Bag 49, Welshpool DC, Perth, Western Australia 6986, Australia. ²⁰CNR-Institute for Ecosystem Studies, Viale dell'Università 32, 00185 Rome, Italy. ²¹Zoological Institute, Russian Academy of Sciences, 199034 St. Petersburg, Universitetskaya nab.1, Russia. ²²Museo Regionale di Scienze Naturali, Via G. Giolitti, 36, I-10123 Torino, Italy. ²³Taronga Conservation Society Australia, Taronga Zoo, P.O. Box 20, Mosman 2088, Sydney, Australia. ²⁴Martin Barrios 2230 c/ Pizarro; Barrio Republicano, Asunción, Paraguay. ²⁵Zoological Society of London, Regent's Park, London, NW1 4RY, UK. ²⁶Unidad de Investigación Ecología Terrestre, Centro Nacional Patagónico-CONICET, Boulevard Brown 2915, 9120 Puerto Madryn, Argentina. ²⁷Patagonian and Andean Steppe Program, Wildlife Conservation Society, Boulevard Brown 2915, 9120 Puerto Madryn, Argentina. ²⁸Centre for Biodiversity & Restoration Ecology, School of Biological Sciences, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand. ²⁹Systematics Lab, School of Environmental Studies, University of Delhi, Delhi 110 007, India. ³⁰Center for Biodiversity and Biosecurity Studies, Pacific Institute for Sustainable Development, Jalan Bumi Nyir 101, Manado, North Sulawesi, Indonesia. ³¹Facultad de Ciencias Naturales e Instituto Miguel Lillo, Universidad Nacional de Tucumán, Miguel Lillo 205, 4000 SM de Tucumán, Tucumán, Argentina. ³²P.O. Box 47074, Nairobi 00100, Kenya. ³³Escuela de Biología, Universidad de Costa Rica, San Pedro, 11501-2060 San José, Costa Rica. ³⁴Sección de Zoología, Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Universidad del Valle, Calle 13, No. 100-00, Cali, Colombia. ³⁵Earthwatch Institute, 256 Banbury Road, Oxford OX2 7DE, UK. ³⁶Veterinary Biomedical Sciences, Royal (Dick) School of Veterinary Studies, University of Edinburgh, Summerhall, Edinburgh EH9 1QH, Scotland, UK. ³⁷47B Lewisham Hill, London SE13 7PL, UK. ³⁸Laboratorio de Herpetología, Universidad del Valle, Carrera 51, No. 8H-15, Cali, Colombia. ³⁹WWF Italy-Species Office, Via Po 25/c 00198 Rome, Italy. ⁴⁰British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK. ⁴¹Biodiversity and Conservation Biology Department, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa. ⁴²Bio-Amazonia Conservation International, 1295 William Street, Baltimore, MD 21230, USA. ⁴³Universidade Federal do Amazonas, Depto Ciências Pesqueiras, Manaus, AM 60700, Brazil. ⁴⁴National Museum of Marine Biology and aquarium, 2 Houwan Road, Checheng, Pingtung 944, Taiwan, R.O.C. ⁴⁵United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, UK. ⁴⁶Department of Animal and Human Biology, Sapienza Università di Roma, Viale dell'Università 32, 00185 Roma, Italy. ⁴⁷Senckenberg Museum of Natural History Goerlitz, PF 300 154, 02806 Goerlitz, Germany. ⁴⁸National Marine Fisheries Service Systematics Laboratory, National Museum of Natural History, MRC-0153, Smithsonian Institution, Washington, DC 20013, USA. ⁴⁹Av. Busch, Edificio Girasoles 2, Piso 5, Depto 7, La Paz, Bolivia. ⁵⁰Department of Marine Sciences, University of Puerto Rico, P.O. Box 9000, Mayagüez, PR 00681, USA. ⁵¹Department of Biology, Northern Michigan University, Marquette, MI 49855, USA. ⁵²Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada. ⁵³Herpetology Section, Zoology Division, National Museum of the Philippines, Padre Burgos Avenue, Ermita 1000, Manila, Philippines. ⁵⁴South African National Biodiversity Institute, KRC, Private Bag X7, Claremont 7735, South Africa. ⁵⁵P.O. Box 5573, Vientiane, Lao PDR. ⁵⁶c/o Birds Australia, 60 Leicester Street, Carlton, Victoria 3053, Australia. ⁵⁷North Orissa University, Sriram Chandra Vihar, Takatpur, Baripada 757003, Dist: Mayurbhanj, Orissa, India. ⁵⁸IUCN SSC African Rhino Specialist Group, Box 1212, Hilton 3245, South Africa. ⁵⁹Herbarium, Library, Art & Archives, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, UK. ⁶⁰NatureBureau, 36 Kingfisher Court, Hambridge Road, Newbury RG14 5SJ, UK. ⁶¹Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany. ⁶²Minnesota Department of Natural Resources, Grand Rapids, MN 55744, USA. ⁶³Nature Protection Trust of Seychelles, 133 Cherry Hinton Road, Cambridge CB1 7BX, UK. ⁶⁴Department of Zoology, Natural History Museum, London SW7 5BD, UK. ⁶⁵San Diego Zoo Institute for Conservation Research, 15600 San Pasqual Valley Road, Escondido, CA 92027, USA. ⁶⁶NatureServe, 746 Middlepoint Road, Port Townsend, WA 98368, USA. ⁶⁷Department of Ecosystem and Conservation Science, University of Montana, Missoula, MT 59812, USA. ⁶⁸Field Museum of Natural History, Chicago, IL 60605, USA. ⁶⁹Department of Biology, Pennsylvania State University, University Park, PA 16802, USA. ⁷⁰Environmental Futures Centre, School of Environment, Griffith University, Gold Coast campus, Queensland, 4222, Australia. ⁷¹Wildfowl & Wetlands Trust, Slimbridge, Glos GL2 7BT, UK. ⁷²Wildlife Institute of India, Post Box #18, Dehra Dun, 248001 Uttarakhand, India. ⁷³Calle Arica 371, Dpto U-2, Miraflores, Lima 18, Perú. ⁷⁴School of Arts and Sciences, Tokyo Woman's Christian University, Zempukuiji 2-6-1, Suginami-ku, Tokyo 167-8585, Japan. ⁷⁵School of Life Sciences and Technology, Institut Teknologi Bandung, 10, Jalan Ganesa, Bandung 40132, Indonesia. ⁷⁶Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, Kent CT2 7NR, UK. ⁷⁷School of the Environment and Natural Resources, Bangor University, Bangor LL57 2UW, UK. ⁷⁸Madagasikara Voakajy, B.P. 5181, Antananarivo (101), Madagascar. ⁷⁹Iwate Prefectural University, Sugo 152-52, Takizawa, Iwate 020-0193, Japan. ⁸⁰Route de la Baroche 12, 2952 Cornol, Switzerland. ⁸¹Raffles Museum of Biodiversity Research, National University of Singapore, Department of Biological Sciences, 6 Science Drive 2, #03-01, 117546, Singapore. ⁸²Norwegian Polar Institute, 9296 Tromsø, Norway. ⁸³Institute of Ecology and Evolution, Russian Academy of Sciences, Leninsky Prospect, 33, Moscow 119071, Russia. ⁸⁴Laboratorio de Biogeografía, Escuela de Geografía, Universidad de Los Andes, Mérida 5101, Venezuela. ⁸⁵IUCN Species Programme, c/o 406 Randolph Hill Road, Randolph, NH 03593, USA. ⁸⁶Kadoorie Farm & Botanic Garden, Lam Kam Road, Tai Po, New Territories, Hong Kong SAR. ⁸⁷Instituto de Herpetología, Fundación Miguel Lillo-CONICET, Miguel Lillo 251, 4000 SM de Tucumán, Tucumán, Argentina. ⁸⁸Conservation Breeding Specialist Group-Eurpam Regional Office, p/a Annuntienstraat 6, 2170 Merksem, Belgium. ⁸⁹Biology Department, San Diego State University, San Diego, CA 92182, USA. ⁹⁰Instituto Nacional de Antropología y Pensamiento Latinoamericano, 3 de Febrero 1378, 1426 Buenos Aires, Argentina. ⁹¹Ecology and Evolutionary Biology, Faculty of Biomedical & Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, Scotland, UK. ⁹²Department of Ecology and Evolutionary Biology, University of California, Irvine, CA 92697, USA. ⁹³ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, 4811, Australia. ⁹⁴Department of Biology, Chemistry and Health Science, Manchester Metropolitan University, Manchester M1 5GD, UK. ⁹⁵World Pheasant Association, Newcastle University Biology Field Station, Close House Estate, Heddon on the Wall, Newcastle upon Tyne NE15 0HT, UK. ⁹⁶115 Suez Road, Cambridge CB1 3QD, UK. ⁹⁷Wildlife Trust Alliance, Box 2031, Arusha, Tanzania. ⁹⁸Zoo Outreach Organisation, 9A Lal Bahadur Colony, Peelamedu, Coimbatore, Tamil Nadu 641004, India. ⁹⁹El Colegio de la Frontera Sur, Apartado postal 63, Carretera Panamericana y Periférico sur s/n Col. María Auxiliadora, 29290, San Cristóbal de las Casas, Chiapas, México. ¹⁰⁰Virginia Institute of Marine Science, Gloucester Point, VA 23062, USA. ¹⁰¹CAT, P.O. Box 332, Cape Neddick, ME 03902, USA. ¹⁰²Division of Reptiles and Amphibians, Museum of Zoology, University of Michigan, Ann Arbor, MI 48109, USA. ¹⁰³Warsaw University of Life Sciences, Ciszewskiego 8, 02-786 Warsaw, Poland. ¹⁰⁴Museum of Vertebrate Zoology, University of California, Berkeley, CA 94720, USA. ¹⁰⁵Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, 04510 Ciudad Universitaria, México. ¹⁰⁶Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 3333 North Torrey Pines Court, La Jolla, CA 92037, USA. ¹⁰⁷International Sturgeon Research Institute, P.O. Box 41635-3464, Rasht, Iran. ¹⁰⁸Centre for Ecology and Conservation, University of Exeter in Cornwall, Penryn TR10 9EZ, UK. ¹⁰⁹Department of Ornithology and Mammalogy, California Academy of Sciences (San Francisco), c/o P.O. Box 202, Cambria, CA 93428, USA. ¹¹⁰USGS Patuxent Wildlife Research Center, MRC 111, National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, Washington, DC 20013, USA. ¹¹¹Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, MA 01462, USA. ¹¹²Herpetology Department, South Australian Museum, North Terrace, Adelaide, South Australia 5000, Australia. ¹¹³Rapid Assessment Program, Conservation International, P.O. Box 1024, Atherton, Queensland 4883, Australia. ¹¹⁴German Technical Cooperation (GTZ) GmbH, Pasaje Bernardo Alcedo N° 150, piso 4, El Olivar, San Isidro, Lima 27, Perú. ¹¹⁵Museo de Zoología, Escuela de Biología, Pontificia Universidad Católica del Ecuador, Av. 12 de Octubre y Veintimilla, Quito, Ecuador. ¹¹⁶School of Biological Sciences, University of Hong Kong, Pok Fu Lam Road, Hong Kong SAR. ¹¹⁷Society for the Conservation of Reef Fish Aggregations, 9888 Carroll Centre Road, Suite 102, San Diego, CA 92126, USA. ¹¹⁸School of Earth and Environmental Sciences, Darling Building, University of Adelaide, North Terrace, Adelaide 5005, Australia. ¹¹⁹Departamento de Biología Evolutiva, Facultad de Ciencias, Universidad Nacional Autónoma de México, Circuito Exterior S/N, 04510, Ciudad Universitaria, México. ¹²⁰Big Island Invasive Species Committee, Pacific Cooperative Studies Unit, University of Hawaii, 23 East Kawili Street, Hilo, HI 96720, USA. ¹²¹Sirenian International, 200 Stonewall Drive, Fredericksburg, VA 22401, USA. ¹²²Department of Biology, P.O. Box 8042, Georgia Southern University, Statesboro, GA 30460, USA. ¹²³IUCN SSC Tapir Specialist Group, 330 Shareditch Road, Columbia, SC 29210, USA. ¹²⁴Department of Natural Resources and the Environment, University of New Hampshire, Jackson Estuarine Laboratory, Durham, NH 03824, USA. ¹²⁵Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Recanati-Kaplan Centre, Tubney House, Tubney OX13 5QL, UK. ¹²⁶Laboratório de Zoologia, Universidade Católica de Brasília, Campus I-Q.S. 07 Lote 01 EPTC-Taguatinga-DF, 71966-700, Brazil. ¹²⁷School of Life Sciences, Arizona State University, Tempe, AZ 85287, USA. ¹²⁸Royal Museum for Central Africa, Ichthyology, Leuvensesteenweg 13, B-3080 Tervuren, Belgium. ¹²⁹Katholieke Universiteit Leuven, Laboratory of Animal Diversity and Systematics, Charles Deberiotstraat 32, B-3000 Leuven, Belgium. ¹³⁰Center for International Forestry Research, Jalan CIFOR, Situ Gede, Bogor Barat 16115, Indonesia. ¹³¹Aaryak and International Rhino Foundation, 50 Samarwoy Path (Survey), Post Office Beltola, Guwahati-781 028, Assam, India. ¹³²The Biodiversity Consultancy Ltd., 4 Woodend, Trumpington, Cambridge CB2 9LJ, UK. ¹³³2313 Willard Avenue, Madison, WI 53704, USA. ¹³⁴Edward Grey Institute, Department of Zoology, University of Oxford, Oxford OX1 3PS, UK. ¹³⁵Vertebrate Research Division, National Institute of Biological Resources, Environmental Research Complex, Gyoungseo-dong, Seo-gu, Incheon 404-708, South Korea. ¹³⁶South African Institute for Aquatic Biodiversity, P/Bag 1015, Grahamstown, 6140, South Africa. ¹³⁷Departamento de Zoología, Centro Regional Universitario Bariloche, Universidad Nacional del Comahue, Quintral 1250, 8400 Bariloche, Argentina. ¹³⁸Emilio Goeldi Museum, Av. Perimetral, 1901, Belém, Pará 66017-970, Brazil. ¹³⁹Federal University of Pará, Rua Augusto Corrêa, 01, Belém, Pará 66075-110, Brazil. ¹⁴⁰Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Casilla 6553, Santiago, Chile. ¹⁴¹Department of Psychology, University of Stirling, Stirling FK9 4LA, Scotland, UK. ¹⁴²Chengdu Institute of Biology, the Chinese Academy of Sciences, Chengdu, 610041, P.R. China. ¹⁴³Department of Ecology and Evolution, Stony Brook University, Stony Brook, NY 11794, USA. ¹⁴⁴IUCN SSC, African Elephant Specialist Group, c/o IUCN ESARO, P.O. Box 68200, Nairobi 00200, Kenya. ¹⁴⁵Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, USA. ¹⁴⁶Global Environment Facility, 1818 H Street NW, G 6-602, Washington, DC 20433, USA. ¹⁴⁷Department of Zoology, Federal University of Minas Gerais, 31270-901, Belo Horizonte, Brazil. ¹⁴⁸Centre for Population Biology, Imperial College London, Silwood Park, Ascot, Berks SL5 7PY, UK. ¹⁴⁹IUCN, 28 Rue Mauverney, CH-1196 Gland, Switzerland. ¹⁵⁰North of England Zoological Society, Chester Zoo, Upton-by-Chester, Chester CH2 1LH, UK. ¹⁵¹Centro de Ecología, Instituto Venezolano de Investigaciones Científicas, Apartado 20632, Caracas 1020-A, Venezuela, and Provita, Apartado 47552, Caracas 1041-A, Venezuela. ¹⁵²Department of Conservation Ecology and Entomology, Stellenbosch University, P/Bag X1, Matieland 7602, South Africa. ¹⁵³National Wildlife Federation, 901 E Street NW, Suite 400, Washington, DC 20004, USA. ¹⁵⁴Department of Biology and Biochemistry, University of Bath, Bath BA2 7AY, UK. ¹⁵⁵Al Ain Wildlife Park & Resort, P.O. Box 45553, Abu Dhabi, United Arab Emirates.

*To whom correspondence should be addressed. E-mail: mike.hoffmann@iucn.org

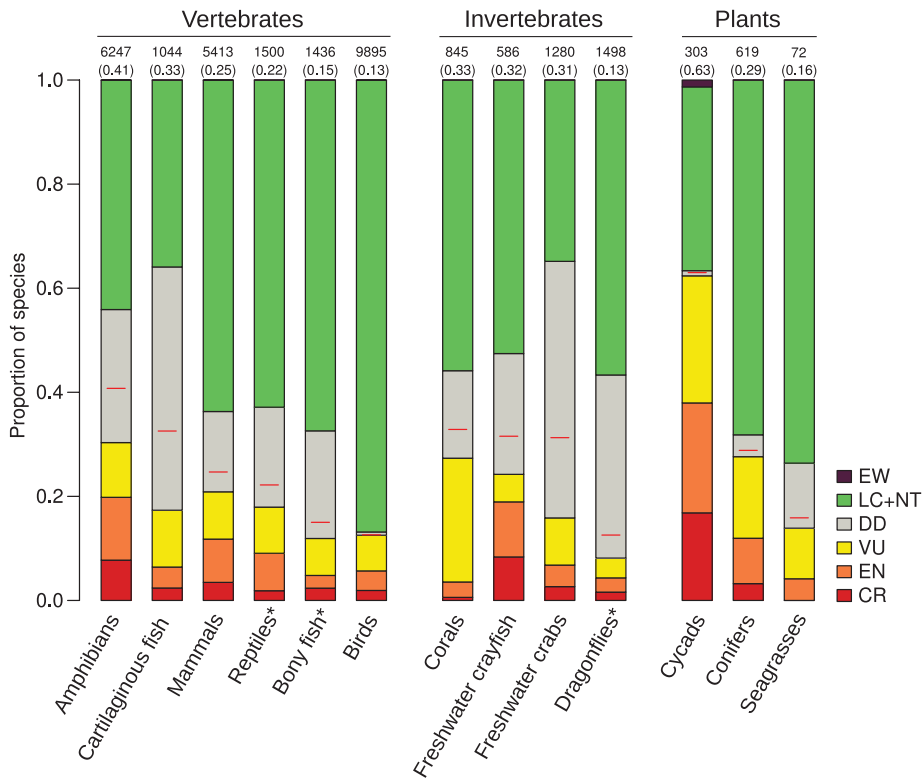


Fig. 1. The proportion of vertebrate species in different Red List categories compared with completely (or representatively) assessed invertebrate and plant taxa on the 2010 IUCN Red List (15). EW, Extinct in the Wild; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient. Extinct species are excluded. Taxa are ordered according to the estimated percentage (shown by horizontal red lines and given in parentheses at tops of bars) of extant species considered Threatened if Data Deficient species are Threatened in the same proportion as data-sufficient species. Numbers above the bars represent numbers of extant species assessed in the group; asterisks indicate those groups in which estimates are derived from a randomized sampling approach.

representative samples of reptiles and bony fishes [~1500 species each (13)].

The IUCN Red List is the widely accepted standard for assessing species' global risk of extinction according to established quantitative criteria (14). Species are categorized in one of eight categories of extinction risk, with those in the categories Critically Endangered, Endangered, or Vulnerable classified as Threatened. Assessments are designed to be transparent, objective, and consultative, increasingly facilitated through workshops and Web-based open-access systems. All data are made freely available for consultation (15) and can therefore be challenged and improved upon as part of an iterative process toward ensuring repeatable assessments over time.

Status, trends, and threats. Almost one-fifth of extant vertebrate species are classified as Threatened, ranging from 13% of birds to 41% of amphibians, which is broadly comparable with the range observed in the few invertebrate and plant taxa completely or representatively assessed to date (Fig. 1 and table S2). When we incorporate the uncertainty that Data Deficient species (those with insufficient information for determining risk of extinction) introduce, the proportion of all vertebrate species classified as Threatened is between 16% and 33% (midpoint = 19%; table S3). [Further details of the data and assumptions behind these values are provided in (16) and tables S2 and S3.] Threatened vertebrates occur mainly in tropical regions (Fig. 2), and these concentrations are generally disproportionately high even when accounting for their high overall species

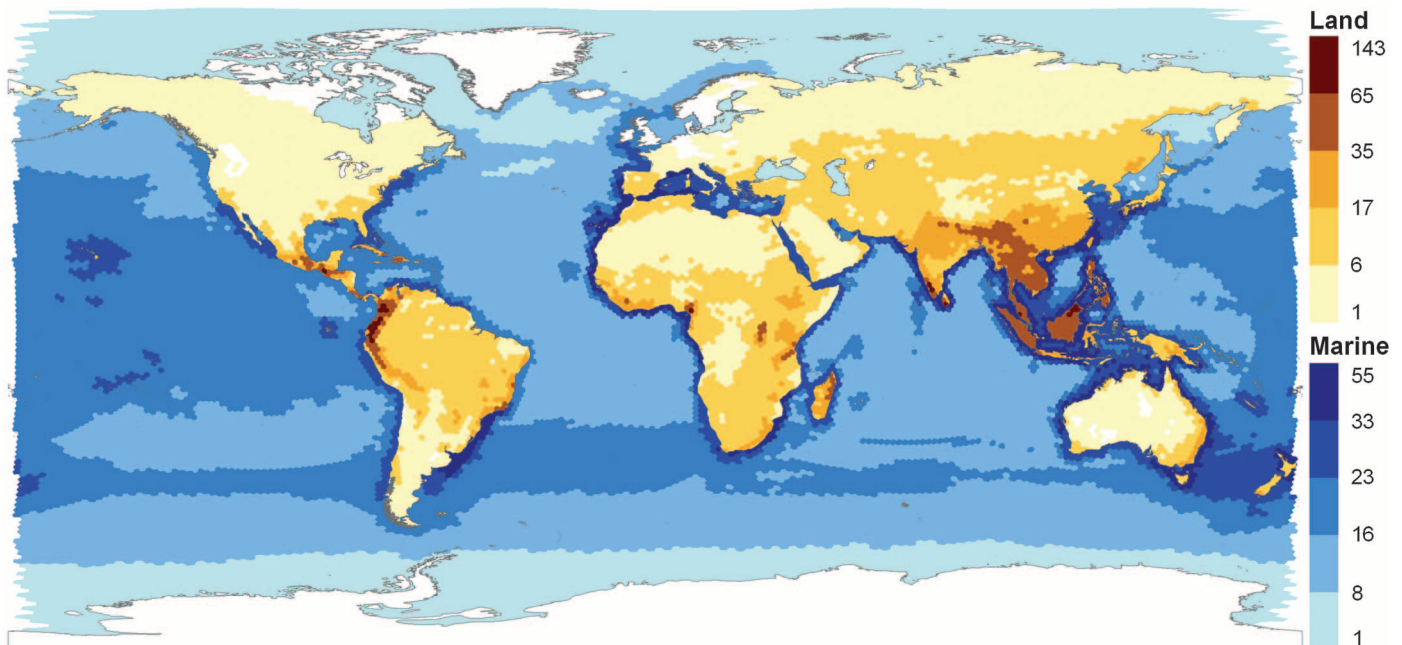


Fig. 2. Global patterns of threat, for land (terrestrial and freshwater, in brown) and marine (in blue) vertebrates, based on the number of globally Threatened species in total.

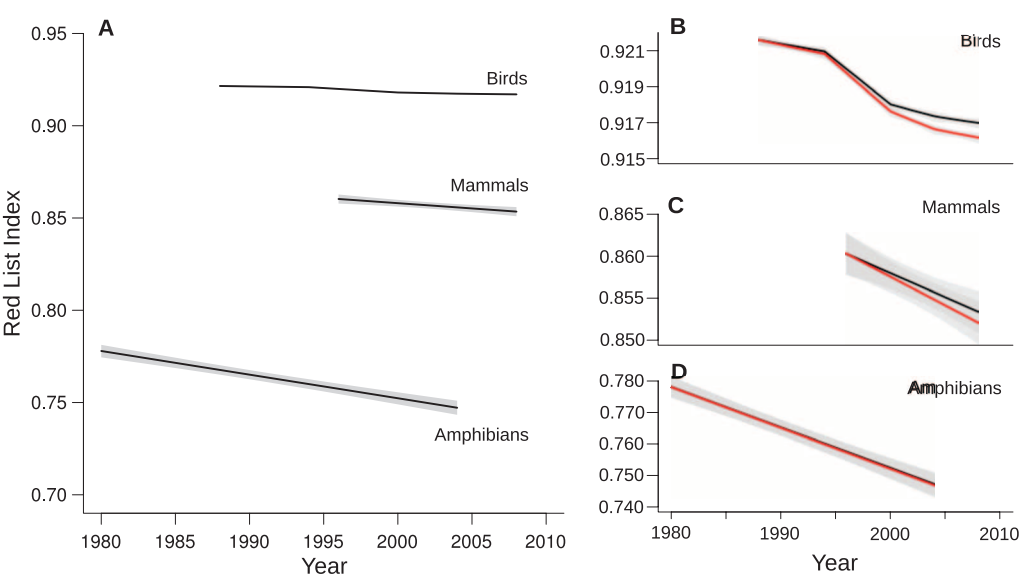
richness (fig. S4, A and B). These patterns highlight regions where large numbers of species with restricted distributions (17) coincide with intensive direct and indirect anthropogenic pressures, such as deforestation (18) and fisheries (19). To investigate temporal trends in extinction risk of vertebrates, we used the IUCN Red List Index (RLI) methodology (20) that has been

Table 1. Net number of species qualifying for revised IUCN Red List categories between assessments owing to genuine improvement or deterioration in status, for birds (1988 to 2008), mammals (1996 to 2008), and amphibians (1980 to 2004). Category abbreviations are as for Fig. 1; CR(PE/PEW) denotes Critically Endangered (Possibly Extinct or Possibly Extinct in the Wild). CR excludes PE/PEW. Species undergoing an improvement (i.e., moving from a higher to a lower category of threat) are indicated by "+"; species de-

teriorating in status (i.e., moving from a lower to a higher category of threat) are indicated by "-". Species changing categories for nongenuine reasons, such as improved knowledge or revised taxonomy, are excluded. In the case of birds, for which multiple assessments have been undertaken, values in parentheses correspond to the sum of all changes between consecutive assessments; the same species may therefore contribute to the table more than once [see (16)].

		Red List category at end of period							
		Red List category at end of period							
		EX	EW	CR (PE/PEW)	CR	EN	VU	NT	LC
Red List category at start of period	Birds	EX	0	0	0	0	0	0	0
		EW	0	0	+1 (+1)	0	0	0	0
		CR (PE/PEW)	0	0	0	0	0	0	0
		CR	-2 (-2)	-2 (-2)	-7 (-7)	+16 (+19)	+1 (+3)	0	0
		EN	0	0	0	-22 (-27)	+4 (+5)	0	0
		VU	0	0	0	-10 (-11)	-34 (-41)	+9 (+10)	0 (+1)
		NT	0	0	0	-4 (-4)	-5 (-2)	-40 (-47)	+1 (+1)
		LC	0	0	0	-1 (0)	-5 (-4)	-5 (-5)	-78 (-81)
	Mammals	EX	0	0	0	0	0	0	0
		EW	0	0	+1	+1	0	0	0
		CR (PE/PEW)	0	0	0	0	0	0	0
		CR	0	-1	-3	+3	+2	0	0
		EN	0	0	0	-31	+3	+1	0
		VU	0	0	0	-2	-39	+5	+1
		NT	0	0	0	-1	-4	-47	+7
		LC	0	0	0	0	-2	-2	-39
	Amphibians	EX	0	0	0	0	0	0	0
		EW	0	0	0	0	0	0	0
		CR (PE/PEW)	-2	0	0	0	0	0	0
		CR	-3	-1	-34	0	+2	0	0
		EN	-2	0	-42	-77	0	+2	0
		VU	-2	0	-19	-51	-45	0	0
		NT	0	0	0	-7	-18	-32	0
		LC	0	0	0	-3	-8	-20	-92

Fig. 3. (A) Trends in the Red List Index (RLI) for the world's birds, mammals, and amphibians. (B to D) Observed change in the RLI for each group (black) compared with RLI trends that would be expected if species that underwent an improvement in status due to conservation action had undergone no change (red). The difference is attributable to conservation. An RLI value of 1 equates to all species being Least Concern; an RLI value of 0 equates to all species being Extinct. Improvements in species conservation status lead to increases in the RLI; deteriorations lead to declines. A downward trend in the RLI value means that the net expected rate of species extinctions is increasing. Shading shows 95% confidence intervals. Note: RLI scales for (B), (C), and (D) vary.



adopted for reporting against global targets (1, 2). We calculated the change in RLI for birds (1988, 1994, 2000, 2004, and 2008), mammals (1996 and 2008), and amphibians (1980 and 2004); global trend data are not yet available for other vertebrate groups, although regional indices have been developed (21). The RLI methodology is explained in detail in (16), but in summary the index is an aggregated measure of extinction risk calculated from the Red List categories of all assessed species in a taxon, excluding Data Deficient species. Changes in the RLI over time result from species changing categories between assessments (Table 1). Only real improvements or deteriorations in status (termed “genuine” changes) are considered; re-categorizations attributable to improved knowledge, taxonomy, or criteria change (“nongenuine” changes) are excluded (22). Accordingly, the RLI is calculated only after earlier Red List categorizations are retrospectively corrected using current information and taxonomy, to ensure that the same species are considered throughout and that only genuine changes are included. For example, the greater red musk shrew (*Crocidura flavescens*) was classified as Vulnerable in 1996 and as Least Concern in 2008; however, current evidence indicates that the species was also Least Concern in 1996, and the apparent improvement is therefore a nongenuine change. In contrast, Hose’s broadbill (*Calyptomena hosii*)

was one of 72 bird species to deteriorate one Red List category between 1994 and 2000, from Least Concern to Near Threatened, mainly because of accelerating habitat loss in the Sundaic lowlands in the 1990s. Such a deterioration in a species’ conservation status leads to a decline in the RLI (corresponding to increased aggregated extinction risk); an improvement would lead to an increase in the RLI.

Temporal trajectories reveal declining RLIs for all three taxa. Among birds, the RLI (Fig. 3A) showed that their status deteriorated from 1988 to 2008, with index values declining by 0.49%, an average of 0.02% per year (table S4). For mammals, the RLI declined by 0.8% from 1996 to 2008, a faster rate (0.07% per year) than for birds. Proportionally, amphibians were more threatened than either birds or mammals; RLI values declined 3.4% from 1980 to 2004 (0.14% per year). Although the absolute and proportional declines in RLIs for each taxonomic group were small, these represent considerable biodiversity losses. For example, the deterioration for amphibians was equivalent to 662 amphibian species each moving one Red List category closer to extinction over the assessment period. The deteriorations for birds and mammals equate to 223 and 156 species, respectively, deteriorating at least one category. On average, 52 species per year moved one Red List category closer to extinction from 1980 to

2008. Note that the RLI does not reflect ongoing population changes that are occurring too slowly to trigger change to different categories of threat. Other indicators based on vertebrate population sizes showed declines of 30% between 1970 and 2007 (1, 2, 22).

Global patterns of increase in overall extinction risk are most marked in Southeast Asia (Fig. 4 and figs. S5A and S6). It is known that the planting of perennial export crops (such as oil palm), commercial hardwood timber operations, agricultural conversion to rice paddies, and unsustainable hunting have been detrimental to species in the region (23), but here we show the accelerating rate at which these forces are driving change. In California, Central America, the tropical Andean regions of South America, and Australia, patterns have been driven mainly by the “enigmatic” deteriorations among amphibians (24), which have increasingly been linked to the infectious disease chytridiomycosis, caused by the presumed invasive fungal pathogen *Batrachochytrium dendrobatidis* (25). Almost 40 amphibians have deteriorated in status by three or more IUCN Red List categories between 1980 and 2004 (Table 1).

Although chytridiomycosis has been perhaps the most virulent threat affecting vertebrates to emerge in recent years, it is not the only novel cause of rapid declines. The toxic effects of the veterinary drug diclofenac on Asian vultures have

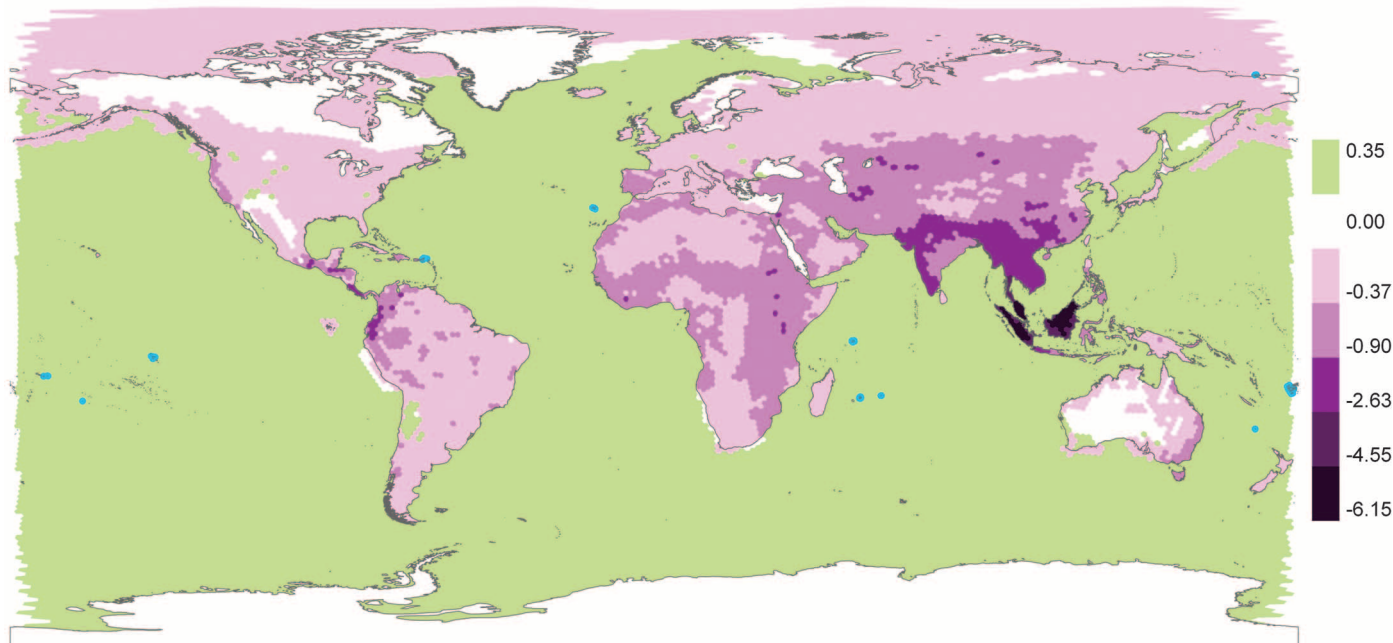


Fig. 4. Global patterns of net change in overall extinction risk across birds, mammals, and amphibians (for the periods plotted in Fig. 3) mapped as average number of genuine Red List category changes per cell per year. Purple corresponds to net deterioration (i.e., net increase in extinction risk) in that cell; green, net improvement (i.e., decrease in extinction risk); white, no change. The uniform pattern of improvement at sea is driven by improvements of migratory marine mammals with

cosmopolitan distributions (e.g., the humpback whale). Deteriorations on islands [e.g., the nightingale reed-warbler (*Acrocephalus luscinius*) in the Northern Mariana Islands] and improvements on islands [e.g., the Rarotonga monarch (*Pomarea dimidiata*) in the Cook Islands] are hard to discern; islands showing overall net improvements are shown in blue. Note that the intensity of improvements never matches the intensity of deteriorations.

caused estimated population declines exceeding 99% over the past two decades in certain *Gyps* species, and have resulted in three species moving from Near Threatened to Critically Endangered between 1994 and 2000. Numbers of Tasmanian devils (*Sarcophilus harrisii*) have fallen by more than 60% in the past 10 years because of the emergence of devil facial tumor disease (resulting in three step changes from Least Concern to Endangered). Climate change is not yet adequately captured by the IUCN Red List (26, 27) but has been directly implicated in the deteriorating status of several vertebrates and may interact with other threats to hasten extinction (28). However, there is no evidence of a parallel to the systemwide deteriorations documented for reef-building corals affected by bleaching events related to El Niño–Southern Oscillation occurrences (29).

Most deteriorations in status are reversible, but in 13% of cases they have resulted in extinction. Two bird species—the kamao (*Myadestes myadestinus*) from Hawaii and the Alaotra grebe (*Tachybaptus rufolavatus*) from Madagascar—became extinct between 1988 and 2008, and a further six Critically Endangered species have been flagged as “possibly extinct” during this period (Table 1 and table S5). At least nine amphibian species vanished during the two decades after 1980, including the golden toad (*Incilius periglenes*) from Costa Rica and both of Australia’s unique gastric-brooding frog species (genus *Rheobatrachus*); a further 95 became possibly extinct, 18 of them harlequin toads in the Neotropical genus *Atelopus* (23% of species). No mammals are listed as Extinct for the period 1996 to 2008, although the possible extinction of the Yangtze River dolphin (*Lipotes vexillifer*) would be the first megafauna vertebrate species extinction since the Caribbean monk seal in the 1950s (30).

Estimates of conservation success. These results support previous findings that the state of biodiversity continues to decline, despite increasing trends in responses such as protected areas coverage and adoption of national legislation (1, 2). Next, we asked whether conservation efforts have made any measurable contribution to reducing declines or improving the status of biodiversity.

The RLI trends reported here are derived from 928 cases of recategorization on the IUCN Red List (Table 1 and table S6), but not all of these refer to deteriorations. In 7% of cases (68/928), species underwent an improvement in status, all but four due to conservation action. For example, the Asian crested ibis (*Nipponia nippon*) changed from Critically Endangered in 1994 to Endangered in 2000 owing to protection of nesting trees, control of agrochemicals in rice fields, and prohibition of firearms; the four exceptions were improvements resulting from natural processes, such as unassisted habitat regeneration (tables S7 and S8). Nearly all of these improvements involved mammals

and birds, where the history of conservation extends farther back and where the bulk of species-focused conservation funding and attention is directed (31). Only four amphibian species underwent improvements, because the amphibian extinction crisis is such a new phenomenon and a plan for action has only recently been developed (32).

To estimate the impact of conservation successes, we compared the observed changes in the RLI with the RLI trends expected if all 64 species that underwent an improvement in status due to conservation action had not done so (16). Our explicit assumption is that in the absence of conservation, these species would have remained unchanged in their original category, although we note that this approach is conservative because it is likely that some would have deteriorated [in the sense of (6)]. The resulting difference between the two RLIs can be attributed to conservation. We show that the index would have declined by an additional 18% for both birds and mammals in the absence of conservation (Fig. 3, B and C, and table S4). There was little difference for amphibians (+1.4%; Fig. 3D) given the paucity of species improvements. For birds, conservation action reduced the decline in the RLI from 0.58% to 0.49%, equivalent to preventing 39 species each moving one Red List category closer to extinction between 1988 and 2008. For mammals, conservation action reduced the RLI decline from 0.94% to 0.8%, equivalent to preventing 29 species moving one category closer to extinction between 1996 and 2008.

These results grossly underestimate the impact of conservation, because they do not account for species that either (i) would have deteriorated further in the absence of conservation actions, or (ii) improved numerically, although not enough to change Red List status. As an example among the former, the black stilt (*Himantopus novaezelandiae*) would have gone extinct were it not for reintroduction and predator control efforts, and its Critically Endangered listing has thus remained unchanged (6). Among the latter, conservation efforts improved the total population numbers of 33 Critically Endangered birds during the period 1994 to 2004, but not sufficiently for any species to be moved to a lower category of threat (33). As many as 9% of mammals, birds, and amphibians classified as Threatened or Near Threatened have stable or increasing populations (15) largely due to conservation efforts, but it will take time for these successes to translate into improvements in status. Conservation efforts have also helped to avoid the deterioration in status of Least Concern species. Finally, conservation actions have benefited many other Threatened species besides birds, mammals, and amphibians, but this cannot yet be quantified through the RLI for groups that have been assessed only once [e.g., salmon shark (*Lamna ditropis*) numbers have improved as the result

of a 1992 U.N. moratorium on large-scale pelagic driftnet fisheries].

Confronting threats. Species recovery is complex and case-specific, but threat mitigation is always required. We investigated the main drivers of increased extinction risk by identifying, for each species that deteriorated in status, the primary threat responsible for that change. To understand which drivers of increased extinction risk are being mitigated most successfully, we identified, for each species that improved in status, the primary threat offset by successful conservation (table S6).

We found that for any single threat, regardless of the taxa involved, deteriorations outnumber improvements; conservation actions have not yet succeeded in offsetting any major driver of increased extinction risk (fig. S7). On a per-species basis, amphibians are in an especially dire situation, suffering the double jeopardy of exceptionally high levels of threat coupled with low levels of conservation effort. Still, there are conservation successes among birds and mammals, and here we investigate the degree to which particular threats have been addressed.

Conservation actions have been relatively successful at offsetting the threat of invasive alien species for birds and mammals: For every five species that deteriorated in status because of this threat, two improved through its mitigation. These successes have resulted from the implementation of targeted control or eradication programs [e.g., introduced cats have been eradicated from 37 islands since the mid-1980s (34)] coupled with reintroduction initiatives [e.g., the Seychelles magpie-robin (*Copsychus sechellarum*) population was 12 to 15 birds in 1965 but had increased to 150 birds by 2005 (fig. S8)]. Many of these improvements have occurred on small islands but also in Australia, owing in part to control of the red fox (*Vulpes vulpes*) (Fig. 4 and fig. S5B). However, among amphibians, only a single species—the Mallorcan midwife toad (*Alytes muletensis*)—improved in status as a result of mitigation of the threat posed by invasive alien species, compared with 208 species that deteriorated. This is because there is still a lack of understanding of the pathways by which chytridiomycosis is spread and may be controlled, and in situ conservation management options are only just beginning to be identified [e.g., (35)]. Meanwhile, the establishment of select, targeted captive populations with the goal of reintroducing species in the wild may offer valuable opportunities once impacts in their native habitat are brought under control [e.g., the Kihansi spray toad (*Nectophrynoides asperginis*), categorized as Extinct in the Wild because of drastic alteration of its spray zone habitat].

For mammals and birds, the threats leading to habitat loss have been less effectively addressed relative to that of invasive alien species: For every 10 species deteriorating as a

result of agricultural expansion, fewer than 1 improved because of mitigation of this threat. Protected areas are an essential tool to safeguard biodiversity from habitat loss, but the protected areas network remains incomplete and nonstrategic relative to Threatened species (17), and reserve management can be ineffective (36). Numerous Threatened species are restricted to single sites, many still unprotected (37), and these present key opportunities to slow rates of extinction. In the broader matrix of unprotected land, agri-environmental schemes could offer important biodiversity benefits, provided that management policies are sufficient to enhance populations of Threatened species (38).

Hunting has been relatively poorly addressed in mammals (62 deteriorations, 6 improvements) when compared with birds (31 deteriorations, 9 improvements). In birds, successes have resulted mainly from targeted protection [e.g., Lear's macaw (*Anodorhynchus leari*) changed from Critically Endangered to Endangered as a result of active protection of the Toca Velha/Serra Branca cliffs in Brazil], but also from enforcement of legislation (e.g., hunting bans) and harvest management measures. Many mammals subject to hunting occur at low densities, have large home ranges, and/or are large-bodied. Although active site-based protection has contributed to an improvement in the status of some of these species, site protection alone is often insufficient if not complemented by appropriate legislation, biological management, and effective enforcement (39). For example, a combination of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) and enactment of the Vicuña Convention, which prohibited domestic exploitation and mandated the establishment of protected areas, has helped to improve the status of the vicuña (*Vicuña vicugna*) from Near Threatened to Least Concern.

The threat of fisheries has been mitigated relatively more effectively for marine mammals (4 deteriorations, 2 improvements) than for birds (10 deteriorations, 0 improvements), reflecting both the time when drivers first emerged and the past influence of supranational conservation policy. Among historically exploited, long-lived mammals, for example, the humpback whale (*Megaptera novaeangliae*) has benefited from protection from commercial whaling (since 1955) and has improved from Vulnerable to Least Concern. Declines among slow-breeding seabirds (particularly albatrosses and petrels; fig. S9) are mainly a consequence of increasing incidental by-catch resulting from the growth of commercial fisheries, primarily those that use long-line and trawling methods. Legislative tools, such as the recently enacted multilateral Agreement on the Conservation of Albatrosses and Petrels (40), may yet deliver dividends by coordinating international action to reduce fisheries mortality of these highly migratory species.

Binding legislation and harvest management strategies also are urgently needed to address the disproportionate impact of fisheries on cartilaginous fishes (fig. S10).

We have no data on the relationship between expenditure on biodiversity and conservation success. A disproportionate percentage of annual conservation funding is spent in economically wealthy countries (41), where there are generally fewer Threatened species (Fig. 2 and fig. S4B) and the disparity between success and failure appears less evident (Fig. 4). Southeast Asia, by contrast, has the greatest imbalance between improving and deteriorating trends, emphasizing the need there for greater investment of resources and effort.

Conclusions. Our study confirms previous reports of continued biodiversity losses. We also find evidence of notable conservation successes illustrating that targeted, strategic conservation action can reduce the rate of loss relative to that anticipated without such efforts. Nonetheless, the current level of action is outweighed by the magnitude of threat, and conservation responses will need to be substantially scaled up to combat the extinction crisis. Even with recoveries, many species remain conservation-dependent, requiring sustained, long-term investment (42); for example, actions have been under way for 30 years for the golden lion tamarin (*Leontopithecus rosalia*), 70 years for the whooping crane (*Grus americana*), and 115 years for the white rhinoceros (*Ceratotherium simum*).

Halting biodiversity loss will require coordinated efforts to safeguard and effectively manage critical sites, complemented by broad-scale action to minimize further destruction, degradation, and fragmentation of habitats (37, 39) and to promote sustainable use of productive lands and waters in a way that is supportive to biodiversity. Effective implementation and enforcement of appropriate legislation could deliver quick successes; for example, by-catch mitigation measures, shark-finning bans, and meaningful catch limits have considerable potential to reduce declines in marine species (19). The 2010 biodiversity target may not have been met, but conservation efforts have not been a failure. The challenge is to remedy the current shortfall in conservation action to halt the attrition of global biodiversity.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/science.1194442/DC1
Materials and Methods
Figs. S1 to S10
Tables S1 to S9
References
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