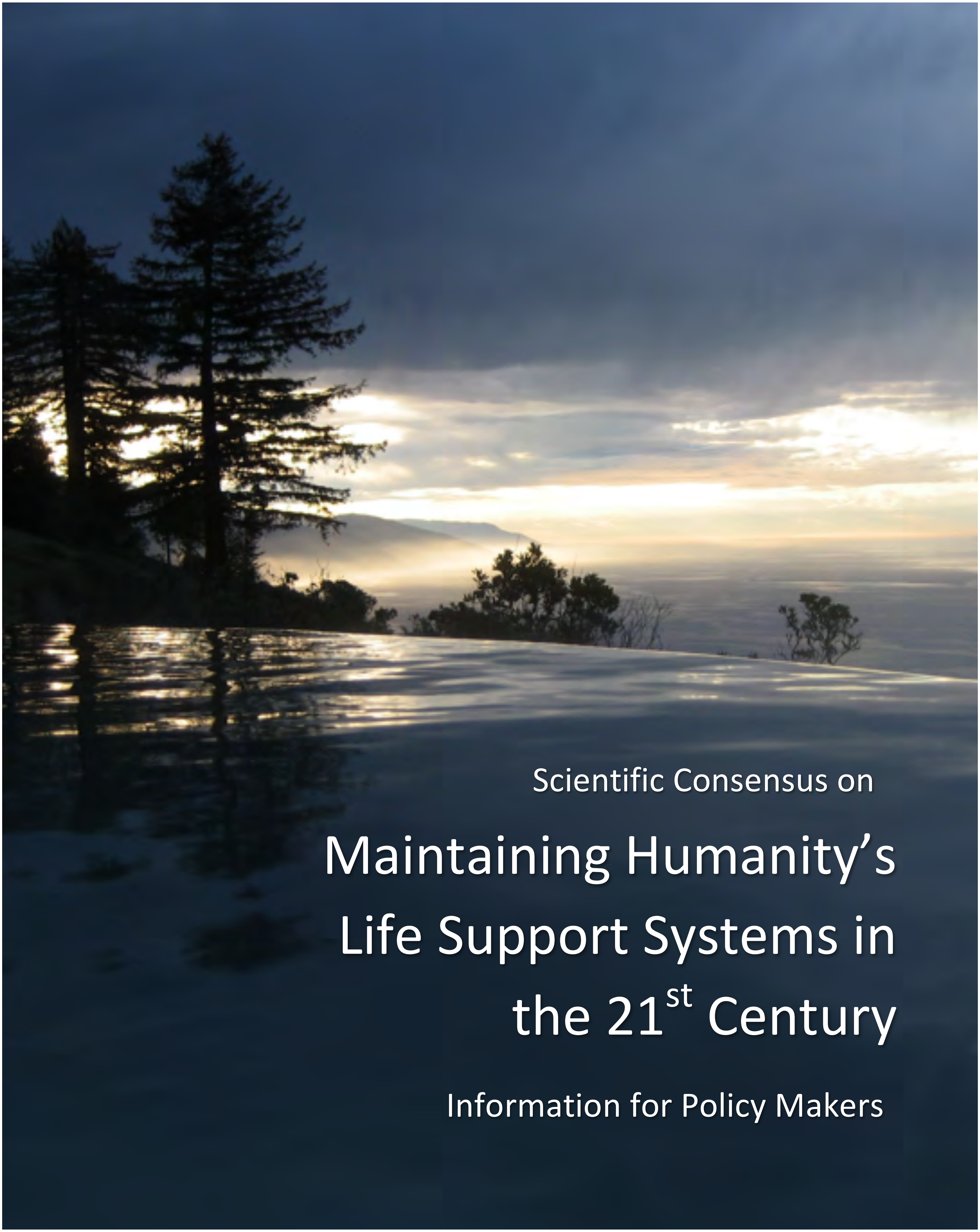


Scientific Consensus on

Maintaining Humanity's Life Support Systems in the 21st Century

Information for Policy Makers

Contents

May 21, 2013

ESSENTIAL POINTS FOR POLICY MAKERS

Scientists' Consensus on

Maintaining Humanity's Life Support Systems in the 21st Century

Earth is rapidly approaching a tipping point. Human impacts are causing alarming levels of harm to our planet. As scientists who study the interaction of people with the rest of the biosphere using a wide range of approaches, we agree that the evidence that humans are damaging their ecological life-support systems is overwhelming.

We further agree that, based on the best scientific information available, human quality of life will suffer substantial degradation by the year 2050 if we continue on our current path.

Science unequivocally demonstrates the human impacts of key concern:

- **Climate disruption**—more, faster climate change than since humans first became a species.
- **Extinctions**—not since the dinosaurs went extinct have so many species and populations died out so fast, both on land and in the oceans.
- **Wholesale loss of diverse ecosystems**—we have plowed, paved, or otherwise transformed more than 40% of Earth's ice-free land, and no place on land or in the sea is free of our direct or indirect influences.
- **Pollution**—environmental contaminants in the air, water and land are at record levels and increasing, seriously harming people and wildlife in unforeseen ways.
- **Human population growth and consumption patterns**—seven billion people alive today will likely grow to 9.5 billion by 2050, and the pressures of heavy material consumption among the middle class and wealthy may well intensify.

Illustration by Cheng (Lily) Li

By the time today's children reach middle age, it is extremely likely that Earth's life-support systems, critical for human prosperity and existence, will be irretrievably damaged by the magnitude, global extent, and combination of these human-caused environmental stressors, **unless we take concrete, immediate actions to ensure a sustainable, high-quality future**.

As members of the scientific community actively involved in assessing the biological and societal impacts of global change, we are sounding this alarm to the world. For humanity's continued health and prosperity, we all—individuals, businesses, political leaders, religious leaders, scientists, and people in every walk of life—must work hard to solve these five global problems, starting today:

1. Climate Disruption
2. Extinctions
3. Loss of Ecosystem Diversity
4. Pollution
5. Human Population Growth and Resource Consumption

Overview of Problems and Broad-Brush Solutions

Climate Disruption

Reduce effects of climate disruption by decreasing greenhouse gas emissions, and by implementing adaptation strategies to deal with the consequences of climate change already underway. Viable approaches include accelerating development and deployment of carbon-neutral energy technologies to replace fossil fuels; making buildings, transportation, manufacturing systems, and settlement patterns more energy-efficient; and conserving forests and regulating land conversion to maximize carbon sequestration. Adapting to the inevitable effects of climate change will be crucial for coastal areas threatened by sea-level rise; ensuring adequate water supplies to many major population centers; maintaining agricultural productivity; and for managing biodiversity and ecosystem reserves.

Extinctions

Slow the very high extinction rates that are leading to a global loss of biodiversity. Viable approaches include assigning economic valuation to the ways natural ecosystems contribute to human well-being; and managing all ecosystems, both in human-dominated regions and in regions far from direct human influence, to sustain and enhance biodiversity and ecosystem services. It will be critical to develop cross-jurisdictional cooperation to recognize and mitigate the interactions of global pressures (for example, climate change, ocean acidification) and local pressures (land transformation, overfishing, poaching endangered species, etc.).

Pollution

Curb the manufacture and release of toxic substances into the environment. Viable approaches include using current science about the molecular mechanisms of toxicity and applying the precautionary principle (verification of no harmful effects) to guide regulation of existing chemicals and design of new ones. We have the knowledge and ability to develop a new generation of materials that are inherently far safer than what is available today.

Overall, we urge the use of the best science available to anticipate most-likely, worst-case, and best-case scenarios for 50 years into the future, in order to emplace policies that guide for environmental health over the long-term as well as adapting to immediate crises.

Ecosystem Transformation

Minimize transformation of Earth's remaining natural ecosystems into farms, suburbs, and other human constructs. Viable agricultural approaches include increasing efficiency in existing food-producing areas; improving food-distribution systems; and decreasing waste. Viable development approaches include enhancing urban landscapes to accommodate growth rather than encouraging suburban sprawl; siting infrastructure to minimize impacts on natural ecosystems; and investing in vital 'green infrastructure,' such as through restoring wetlands, oyster reefs, and forests to secure water quality, flood control, and boost access to recreational benefits.

Population Growth and Consumption

Bring world population growth to an end as early as possible and begin a gradual decline. An achievable target is no more than 8.5 billion people by 2050 and a peak population size of no more than 9 billion, which through natural demographic processes can decrease to less than 7 billion by 2100. Viable approaches include ensuring that everyone has access to education, economic opportunities, and health care, including family planning services, with a special focus on women's rights.

Decrease per-capita resource use, particularly in developed countries. Viable approaches include improving efficiency in production, acquisition, trade, and use of goods and promoting environmentally-friendly changes in consumer behavior.

Statement Drafted Through Collaboration of:

In alphabetical order: Anthony D. Barnosky*, James H. Brown, Gretchen C. Daily, Rodolfo Dirzo, Anne H. Ehrlich, Paul R. Ehrlich, Jussi T. Eronen, Mikael Fortelius, Elizabeth A. Hadly, Estella B. Leopold, Harold A. Mooney, John Peterson Myers, Rosamond L. Naylor, Stephen Palumbi, Nils Christian Stenseth, Marvalee H. Wake

*Lead writer, to whom correspondence should be addressed: barnosky@berkeley.edu

Endorsed by:
(as of 5-21-13 08:00 PM PDT)

A

NAME: David Ackerly
POSITION: Professor, Dept. Integrative Biology
INSTITUTION: Univ. of California, Berkeley
DATE: April 29, 2013

NAME: Dr. Tundi Agardy
POSITION: Executive Director
INSTITUTION: Sound Seas, 26 Van Nuys Rd,
Colrain, MA 01340 USA
DATE: April 26, 2013

NAME: Michael Agliardo, SJ, Ph.D.
POSITION: Assistant Prof.
INSTITUTION: Loyola University Chicago
DATE: May 3, 2013

NAME: Luis F. Aguirre
POSITION: Director
INSTITUTION: Centro de Biodiversidad y Genética, Universidad Mayor de San Simón
DATE: April 25, 2013

NAME: Hossein Akhani
POSITION: Professor of Systematic Botany
INSTITUTION: School of Biology, University of Tehran
DATE: 19.05.2013

NAME: Maria Teresa Alberdi
POSITION: Research Professor
INSTITUTION: Museo Nacional de Ciencias Naturales, CSIC
DATE: 13th May, 2013

NAME: Ross A. Alford
POSITION: Professor (Personal Chair)
INSTITUTION: School of Marine and Tropical Biology, James Cook University, Townsville, Australia
DATE: 19 May 2013

NAME: Caitilyn Allen
POSITION: Professor and Chair of Plant Pathology
INSTITUTION: University of Wisconsin-Madison, USA
DATE: April 26, 2013

NAME: Juan C. Alonso
POSITION: Research Professor
INSTITUTION: Museo Nacional de Ciencias Naturales, Consejo Superior de Investigaciones Científicas, Madrid, SPAIN
DATE: 26 April 2013

NAME: Miguel A. Alonso-Zarazaga (Dr)
POSITION: Tenured Scientist (Entomologist)
INSTITUTION: Museo Nacional de Ciencias Naturales (CSIC), Madrid, Spain
DATE: 25 April 2013

NAME: Peter Alpert
POSITION: Professor
INSTITUTION: University of Massachusetts -- Amherst
DATE: April 26, 2013

NAME: CARLOS ALONSO ALVAREZ
POSITION: Tenure Scientist (Científico Titular)
INSTITUTION: Consejo Superior de Investigaciones Cientificas (CSIC), Spain
DATE: May 5, 2013

NAME: Ameka, Gabriel
POSITION: Professor of Botany
INSTITUTION: Department of Botany, University of Ghana, Legon, Ghana
DATE: 20/05/2013

NAME: Barbara J. Anderson
POSITION: Research Fellow
INSTITUTION: University of Otago
DATE: 20th May 2013

NAME: Nigel Andrew
POSITION: Associate Professor of Entomology
INSTITUTION: University of New England, Armidale, Australia
DATE: 3rd May 2013

NAME: Arto Annila
POSITION: Professor, Department of Physics
INSTITUTION: University of Helsinki
DATE: May 20, 2013

NAME: Miguel Bastos Araújo
POSITION: Senior Research Scientist
INSTITUTION: National Museum of Natural Sciences, Madrid, Spanish Research Council (CSIC)
DATE: 25/04/2012

NAME: W. Scott Armbruster
POSITION: Professor of Ecology & Evolution
INSTITUTION: University of Portsmouth, UK, and University of Alaska, Fairbanks
DATE: 7 May 2013

NAME: Kenneth J. Arrow
POSITION: Professor Emeritus of Management Science and Engineering
INSTITUTION: Stanford University
DATE: Monday, 20 May 2013

NAME: Beatriz Arroyo
POSITION: Researcher
INSTITUTION: Instituto de Investigación en Recursos Cinegéticos (IREC)
DATE: 7/05/2013

NAME: Dr. Mary T. K. Arroyo
POSITION: Director and Full Professor of Biology
INSTITUTION: Institute of Ecology and Biodiversity (IEB)
DATE: 30 April, 2013

NAME: JOAQUIN ARROYO-CABRALES
POSITION: SENIOR SCIENTIST
INSTITUTION: INSTITUTO NACIONAL DE ANTROPOLOGIA E HISTORIA, MEXICO
DATE: 10 MAY 2013

NAME: Khalid Aziz
POSITION: Otto N Miller Professor Emeritus, Energy Resources Engineering
INSTITUTION: Stanford University
DATE: May 20, 2013

B

NAME: Doris Bachtrog
POSITION: Associate Professor
INSTITUTION: UC Berkeley
DATE: April 29, 2013

NAME: Prof. Dr. Franz Bairlein
POSITION: Director
INSTITUTION: Institute of Avian Research, Wilhelmshaven, Germany
DATE: 18 May 2013

NAME: Lela Bakanidze, Ph.D., RBP
POSITION: Professor, Nonproliferation Programs Manager
INSTITUTION: Agricultural University of Georgia, Tbilisi
DATE: 17 May 2013

NAME: Bruce G. Baldwin
POSITION: Professor of Integrative Biology & Curator of the Jepson Herbarium
INSTITUTION: University of California, Berkeley
DATE: 29 April 2013

NAME: Roger C Bales
POSITION: Director, Sierra Nevada Research Institute & Professor, School of Engineering
INSTITUTION: University of California, Merced
DATE: Apr 28, 2013

NAME: Patricia Balvanera
POSITION: Researcher in Ecology
INSTITUTION: Universidad Nacional Autonoma de Mexico
DATE: April 25 2013

NAME: Edward B. Barbier
POSITION: John S. Bugas Professor of Economics, Department of Economics & Finance
INSTITUTION: University of Wyoming
DATE: April 25, 2013

NAME: Anthony D. Barnosky
POSITION: Professor and Curator, Department of Integrative Biology and Museum of Paleontology
INSTITUTION: University of California-Berkeley
DATE: April 23, 2013

NAME: K. Christopher Beard
POSITION: Director, Center for Evolutionary Studies
INSTITUTION: Carnegie Museum of Natural History, Pittsburgh, PA 15213
DATE: May 1, 2013

NAME: Andrew J. Beattie
POSITION: Emeritus Professor
INSTITUTION: Macquarie University, Sydney
DATE: 29 April 2013

NAME: Paul Beier
POSITION: President, Society for Conservation Biology
Regents' Professor
INSTITUTION: School of Forestry, Northern Arizona University, Flagstaff AZ
DATE: April 25, 2013

NAME: Elena Bennett
POSITION: Associate Professor
INSTITUTION: McGill University
DATE: 25 April 2013

NAME: Sally Benson
POSITION: Director, Global Climate and Energy Project
INSTITUTION: Department of Energy Resources Engineering, Stanford University
DATE: March 7, 2013

NAME: Prof Tim Benton
POSITION: Professor of Population Ecology
INSTITUTION: University of Leeds, UK
DATE: April 25, 2013

NAME: Dennis Berg
POSITION: Professor Emeritus
INSTITUTION: California State University, Fullerton
DATE: May 3, 2013

NAME: Eric L Berlow
POSITION: Founder / Adjunct Professor
INSTITUTION: Vibrant Data Labs / University of California Berkeley
DATE: 27 April 2013

NAME: BERTHEAU Yves (PhD, HDR)
POSITION: Directeur de recherche (senior scientist)
INSTITUTION: Inra (Institut national de la recherche agronomique), France
DATE: 2013/05/08

NAME: Robert L. Beschta, PhD
POSITION: Professor Emeritus
INSTITUTION: Forest Ecosystems and Society, Oregon State University
DATE: April 30, 2013

NAME: Martijn Bezemer
POSITION: Senior Scientist
INSTITUTION: Netherlands Institute of Ecology, NIOO-KNAW
DATE: 6 May 2013

NAME: David Blair
POSITION: Adjunct Professor
INSTITUTION: James Cook University
DATE: 20 May 2013

NAME: Jessica L. Blois
POSITION: Assistant Professor
INSTITUTION: University of California, Merced
DATE: 26 April 2013

NAME: Daniel T. Blumstein
POSITION: Professor & Chair, Department of Ecology & Evolutionary Biology and Institute of the Environment & Sustainability
INSTITUTION: University of California Los Angeles
DATE: April 25, 2013

NAME: Carol Boggs
POSITION: Consulting Professor
INSTITUTION: Stanford
DATE: 5/19/2013

NAME: Prof. Katrin Böhning-Gaese
POSITION: Acting Director Biodiversity and Climate Research Centre Frankfurt
INSTITUTION: Biodiversity and Climate Research Centre Frankfurt
DATE: 17.05.2013

NAME: Dr Walter Boles
POSITION: Senior Fellow
INSTITUTION: Australian Museum, Sydney
DATE: 10 May 2013

NAME: Timothy C. Bonebrake
POSITION: Assistant Professor
INSTITUTION: University of Hong Kong
DATE: May 1 2013

NAME: Erik Bonsdorff
POSITION: Professor
INSTITUTION: Department of biosciences, Åbo Akademi University, Finland
DATE: May 15, 2013

NAME: Jeffrey L. Boore
POSITION: Adjunct Professor
INSTITUTION: University of California Berkeley; and
POSITION: Chief Executive Officer
INSTITUTION: Genome Project Solutions, Inc.
DATE: May 2, 2013

NAME: David J Booth
POSITION: Professor of Marine Ecology
INSTITUTION: University of Technology, Sydney
DATE: 26 April 2013

NAME: Derek Booth
POSITION: Adjunct Professor, Bren School of Environmental Science & Management, UC Santa Barbara
Affiliate Professor, Earth and Space Sciences, Univ. of Washington
Senior Editor, Quaternary Research
INSTITUTION: UC Santa Barbara and University of Washington
DATE: May 13, 2013

NAME: ENRIQUE BOSTELMANN TORREALBA
POSITION: ASSOCIATE RESEARCHER
INSTITUTION: 1) LABORATORIO DE ONTOGENIA Y FILOGENIA, DEPARTAMENTO DE BIOLOGÍA, FACULTAD DE CIENCIAS, UNIVERSIDAD DE CHILE, SANTIAGO, CHILE, AND 2) PALEONTOLOGY SECTION, MUSEO NACIONAL DE HISTORIA NATURAL, MONTEVIDEO, URUGUAY.
DATE: MAY 10, 2013

NAME: Yanis Bouchenak-Khelladi
POSITION: Researcher
INSTITUTION: Institute of Systematic

Botany, University of Zurich
DATE: Tuesday 30th of April 2013

NAME: Dr. Mark E. Braun
POSITION: Professor of Social Sciences
INSTITUTION: SUNY-Cobleskill
DATE: May 2, 2013

NAME: David D. Breshears
POSITION: Professor
INSTITUTION: The University of Arizona
DATE: May 13, 2013

NAME: Michael Briguglio
POSITION: Lecturer
INSTITUTION: University of Malta
DATE: April 27, 2013

NAME: Thomas Brooks
POSITION: Head, Science & Knowledge
INSTITUTION: International Union for Conservation of Nature
DATE: 28 Apr 2013

NAME: James H. Brown
POSITION: Professor, Department of Biology,
INSTITUTION: University of New Mexico
DATE: April 23, 2013

NAME: Yvonne Buckley
POSITION: Associate Professor
INSTITUTION: The University of Queensland
DATE: 29/4/13

NAME: April Bullock
POSITION: Professor of Liberal Studies
INSTITUTION: Cal State Fullerton
DATE: May 2,2013

NAME: Nils Bunnefeld
POSITION: Lecturer
INSTITUTION: University of Stirling, UK
DATE: 16 May 2013

NAME: Santiago F. Burneo
POSITION: Curator. Mammal Collection. Museo de Zoología.
INSTITUTION: Pontificia Universidad Católica del Ecuador
DATE: April 25, 2013

NAME: Robyn J. Burnham
POSITION: Associate Professor of Ecology & Evolutionary Biology
INSTITUTION: University of Michigan
DATE: April 24, 2013

NAME: Bruno Alves Buzatto
POSITION: Postdoctoral Research Associate
INSTITUTION: University of Western Australia
DATE: 25/4/2013

C

NAME: Juan Rivero de Aguilar Cachafeiro
POSITION: Biologist
INSTITUTION: MNCN-CSIC
DATE: 25.4.13

NAME: Lawrence B. Cahoon
POSITION: Professor of Biology and Marine Biology
INSTITUTION: UNC Wilmington
DATE: 4/26/13

NAME: John Cairns
POSITION: University Distinguished Professor of Environmental Biology Emeritus
INSTITUTION: Virginia Polytechnic Institute and State University
DATE: April 28, 2013

NAME: Margaret Caldwell
POSITION: Senior Lecturer & Director, Environmental and Natural Resources Law & Policy Program
INSTITUTION: Stanford Law School
DATE: 5/19/13

NAME: José M. Capriles
POSITION: Visiting Scholar, Center for Comparative Archaeology, Department of Anthropology
INSTITUTION: University of Pittsburgh
DATE: May 12th, 2013

NAME: Stephen R. Carpenter
POSITION: Professor and Director
INSTITUTION: Center for Limnology, University of Wisconsin-Madison
DATE: 25 April 2013

NAME: Aurora M Castilla
POSITION: Principal Investigator; Head Department of Biodiversity
INSTITUTION: Qatar Environment & Energy Research Institute
DATE: 13 May 2013

NAME: Juan Carlos Castilla
POSITION: Profesor Titular
INSTITUTION: Pontificia Universidad Católica de Chile
DATE: 21 May 2013

NAME: GERARDO CEBALLOS
POSITION: PROFESSOR.
INSTITUTION: INSITUTO DE ECOLOGIA, UNAM
DATE: APRIL 25, 2013

NAME: C. Page Chamberlain
POSITION: Professor
INSTITUTION: Dept. Environmental Earth System Science, Stanford University
DATE: May 2, 2013

NAME: Laurie Hing Man Chan
POSITION: Professor and Canada Research Chair in Toxicology and Environmental Health; Director, Center for Advanced Research in Environmental Genomics
INSTITUTION: University of Ottawa
DATE: April 29, 2013

NAME: Yvonne Chan
POSITION: Postdoctoral Researcher
INSTITUTION: University of Hawaii
DATE: April 25, 2013

NAME: F. Stuart Chapin, III
POSITION: Professor Emeritus
INSTITUTION: University of Alaska Fairbanks
DATE: May 19, 2013

NAME: Chemin-Roberty Anne
POSITION: Chargée de Coordination et Communication
INSTITUTION: Institut Michel Serres, Ecole normale supérieure de Lyon
DATE: 30/04/2013

NAME: Deliang Chen
POSITION: August Röhss Chair
INSTITUTION: Department of Earth Sciences, University of Gothenburg, Sweden
DATE: 28 April, 2013

NAME: Anne CHENUIL
POSITION: Ph.D. Researcher
INSTITUTION: UMR 7263 (CNRS) – IMBE, Institut Méditerranéen de Biodiversité et d'Ecologie Marine et continentale (IMBE) (Aix-Marseille Université)
DATE: 30 April 2013

NAME: Norman L. Christensen
POSITION: Research Professor and Founding Dean
INSTITUTION: Nicholas School of the Environment, Duke University, Durham, NC 27708
DATE: May 7, 2013

NAME: Patrick Christie
POSITION: Professor, School of Marine and Environmental Affairs and Jackson School of International Studies
INSTITUTION: University of Washington
DATE: April 26th, 2013

NAME: James S Clark
POSITION: Professor
INSTITUTION: Duke University
DATE: Apr 25 2013

NAME: William A. Clemens
POSITION: Curator and Professor Emeritus, University of California Musuem of Paleontology and Department of Integrative Biology
INSTITUTION: University of California Berkeley
DATE: May 1, 2013

NAME: Phyllis D. Coley
POSITION: Distinguished Professor of Biology
INSTITUTION: University of Utah
DATE: April 26, 2013

NAME: Scott L Collins
POSITION: Regent's Professor
INSTITUTION: University of New Mexico
DATE: 4/25/2013

NAME: Patricia Ann Conrad
POSITION: Professor, Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine
INSTITUTION: University of California, Davis
DATE: April 25, 2013

NAME: Caroline S. Conzelman, Ph.D.
POSITION: Associate Director, Global Studies Academic Program; Program Director, Bolivia Global Seminar
Instructor, Anthropology
INSTITUTION: University of Colorado at Boulder
DATE: 28 April 2013

NAME: Jorge Cortés
POSITION: Researcher and Professor of Marine Sciences
INSTITUTION: Universidad de Costa Rica
DATE: 21 May 2013

NAME: Tim Coulson
POSITION: Professor of Zoology
INSTITUTION: University of Oxford
DATE: 7 May 2013

NAME: Denis Couvet
POSITION: Professor
INSTITUTION: Muséum National Histoire Naturelle, Paris
DATE: 26 April 2013

NAME: Pete Coxon
POSITION: Professor of Geography
INSTITUTION: Trinity College Dublin
DATE: 20/05/2013

NAME: Craig Criddle
POSITION: Professor, Department of Civil & Environmental Engineering, and Senior Fellow, Woods institute
INSTITUTION: Stanford University
DATE: 18 May 2013

NAME: JORGE V. CRISCI
POSITION: PROFESSOR OF BIOGEOGRAPHY
INSTITUTION: UNIVERSIDAD NACIONAL DE LA PLATA, ARGENTINA
DATE: MAY 19, 2013

NAME: Larry Crowder
POSITION: Ed Ricketts Professor of Biology and Science Director for the Center for Ocean Solutions
INSTITUTION: Stanford University Hopkins Marine Station
DATE: May 16, 2013

NAME: Lisa M. Curran
POSITION: Professor
INSTITUTION: Stanford University
DATE: 20 May 2013

NAME: CURY, PHILIPPE
POSITION: Senior Scientist and Director of UM EME 212
INSTITUTION: IRD
DATE: 10 May 2013

D

NAME: Gretchen C. Daily
POSITION: Professor
INSTITUTION: Department of Biology and Senior Fellow, Woods Institute, Stanford University
DATE: April 23, 2013

NAME: Edward Davis
POSITION: Fossil Collections Manager
INSTITUTION: University of Oregon Museum of Natural and Cultural History
DATE: 04/25/2013

NAME: Frank W. Davis
POSITION: Professor, Bren School of Environmental Science and Management:
INSTITUTION: University of California, Santa Barbara
DATE: May 6, 2013

NAME: Michael N Dawson
POSITION: Associate Professor
INSTITUTION: School of Natural Sciences, University of California, Merced
DATE: 27 April 2013

NAME: Todd E. Dawson
POSITION: University of California - Berkeley
INSTITUTION: Departments of Integrative Biology -and- Environmental Science, Policy & Management
DATE: 25 April 2013

NAME: Giulio De Leo
POSITION: Professor
INSTITUTION: Department of Biology and Senior Fellow, Woods Institute for the Environment, Stanford University
DATE: May 18 2013

NAME: Sebsebe Demissew, Prof.
POSITION: Professor of Systematic Botany and Angiosperm Phylogeny, Leader of the Ethiopian Flora Project (completed in 2009)
INSTITUTION: Department of Plant Biology and Biodiversity Management, College of Natural Sciences, Adis Ababa University, Addis Ababa, Ethiopia
DATE: 17 May 2013

NAME: Jared Diamond
POSITION: Professor
INSTITUTION: University of California Los Angeles
DATE: May 19, 2013

NAME: Mario Díaz
POSITION: Senior Researcher
INSTITUTION: Dep. Biogeography and Global Change (BGC-MNCN), Museo Nacional de Ciencias Naturales, CSIC, Spain
DATE: 26-4-2013

NAME: Sandra Diaz
POSITION: Full Professor and Senior Principal Investigator
INSTITUTION: Instituto Multidisciplinario de Biologia Vegetal, CONICET
and Universidad Nacional de Cordoba, Argentina.
DATE: 20 May 2013

NAME: Christopher R. Dickman
POSITION: Professor in Terrestrial Ecology
INSTITUTION: The University of Sydney, Australia
DATE: 18 May 2013

NAME: Rodolfo Dirzo,
POSITION: Professor, Department of Biology and Director, Center for Latin American Studies
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: Diane Dodd
POSITION: Assistant Professor
INSTITUTION: University of North Carolina Wilmington
DATE: 4/25/13

NAME: C. Josh Donlan MA PhD
POSITION: Director, Advanced Conservation Strategies; Visiting Professor, Laboratoire Ecologie, Systématique & Evolution,
Université Paris-Sud 11;Fellow, Cornell University
INSTITUTION: Université Paris-Sud 11; Cornell University
DATE: April 26, 2012

NAME: Michael J. Donoghue
POSITION: Sterling Professor of Ecology and Evolutionary Biology
INSTITUTION: Yale University
DATE: April 25, 2013

NAME: Peter Doran
POSITION: Distinguished Professor

INSTITUTION: University of Illinois at Chicago
DATE: April 25, 2013

NAME: Don Driscoll
POSITION: Associate Professor
INSTITUTION: Fenner School of Environment and Society, Australian National University
DATE: 29/4/13

NAME: Robert Dudley
POSITION: Professor
INSTITUTION: University of California, Berkeley
DATE: 29 April 2013

NAME: Ivo Duijnstee
POSITION: Assistant Adjunct Professor
INSTITUTION: Dep. of Integrative Biology, University of California, Berkeley/University of California Museum of Paleontology / Dep. of Earth Sciences, Utrecht University
DATE: April 30, 2013

NAME: John P. Dumbacher
POSITION: Associate Curator of Ornithology and Mammalogy
INSTITUTION: California Academy of Sciences, San Francisco, CA
DATE:13 May 2013

NAME: Robert B. Dunbar
POSITION: W.M. Keck Professor of Earth Sciences
INSTITUTION: Stanford University
DATE: 4/25/13

E

NAME: William E. Easterling
POSITION: Dean, College of Earth and Mineral Sciences
INSTITUTION: The Pennsylvania State University
DATE:1 May 2013

NAME: Alasdair Edwards
POSITION: Emeritus Professor of Coral Reef Ecology
INSTITUTION: Newcastle University, UK
DATE: 17/05/2013

NAME: Bob Edwards
POSITION: Professor of Sociology
INSTITUTION: East Carolina University
DATE: April 26, 2013

NAME: Mary Edwards
POSITION: Professor
INSTITUTION: University of Southampton, Geography and Environment
DATE: 7th May 2013

NAME: Emilie EGEA
POSITION: Technician staff (PhD)
INSTITUTION: Mediterranean Institute for Biodiversity and Ecology, Centre National de la Recherche Scientifique, France
DATE: April 30th 2013

NAME: Anne H. Ehrlich
POSITION: Policy Coordinator and Senior Research Assistant
INSTITUTION: Center for Conservation Biology, Stanford University
DATE: April 23, 2013

NAME: Paul R. Ehrlich
POSITION: Professor, Department of Biology and Center for Conservation Biology
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: STEVEN D. EMSLIE
POSITION: PROFESSOR
INSTITUTION: UNIVERSITY OF NORTH CAROLINA WILMINGTON
DATE: 6 MAY 2013

NAME: Professor Matthew England
POSITION: ARC Laureate Fellow Climate Change Research Centre (CCRC) and ARC Centre of Excellence for Climate System Science
INSTITUTION: The University of New South Wales
DATE: 29 April 2013

NAME: Barend Erasmus
POSITION: Associate professor and Director: Centre for African Ecology
INSTITUTION: University of the Witwatersrand
DATE: 9 May 2013

NAME: Jussi T. Eronen
POSITION: Postdoctoral Researcher
INSTITUTION: Department of Geosciences and Geography, University of Helsinki
DATE: April 23, 2013

NAME: Gilles ESCARGUEL
POSITION: Associate-Professor
INSTITUTION: Dpt. of Earth Sciences, University Lyon 1 (France)
DATE: April, 30th, 2013

NAME: James A. Estes
POSITION: Professor
INSTITUTION: University of California, Santa Cruz
DATE: 25 April 2013

F

NAME: Juan A. Fargallo
POSITION: Researcher
INSTITUTION: Consejo Superior de Investigaciones Científicas (CSIC)
DATE: 13-05-2013

NAME: ALEJANDRO G. FARJI-BRENER
POSITION: INVESTIGADOR , PROFESOR
INSTITUTION: CONICET-ARGENTINA, CENTRO REGIONAL UNIVERSITARIO BARILOCHE, UNIVERSIDAD NACIONAL DEL COMAHUE, ARGENTINA
DATE: 20 DE MAYO 2013

NAME: Marcus W. Feldman, MS, PhD
POSITION: Burnet C. and Mildred Finley Wohlford Professor of Biological Sciences; Director of the Morrison Institute for Population and Resource Studies and Stanford Health Policy Associate
INSTITUTION: Stanford University
DATE: May 19, 2013

NAME: Scott Fendorf
POSITION: Professor
INSTITUTION: Stanford University
DATE: 5/19/2013

NAME: Pablo Ferreras
POSITION: Senior Scientist Research, Spanish Research Council (CSIC)
INSTITUTION: Spanish Game Research Institute (IREC), Ciudad Real, Spain
DATE: May 7th, 2013

NAME: Seth Finnegan
POSITION: Assistant Professor
INSTITUTION: UC Berkeley, Dept. of Integrative Biology
DATE: April 28, 2013

NAME: JON FJELDSÅ
POSITION: PROFESSOR
INSTITUTION: NATURAL HISTORY MUSEUM OF DENMARK, University of Copenhagen, Denmark
DATE: 21. May 2013

NAME: Joern Fischer
POSITION: Professor
INSTITUTION: Leuphana University Lueneburg, Germany
DATE: 18 May 2013

NAME: Matthew Forrest
POSITION: Post-doctoral researcher
INSTITUTION: Biodiversity and Climate Research Centre, Frankfurt am Main, Germany
DATE: 16th May 2013

NAME: Mikael Fortelius
POSITION: Professor, Department of Geosciences and Geography
INSTITUTION: Finnish Museum of Natural History and University of Helsinki
DATE: April 23, 2013

NAME: Carolin Frank
POSITION: Assistant Professor
INSTITUTION: UC Merced
DATE: 4/26/13

NAME: Peter Frumhoff
POSITION: Director of Science and Policy, Chief Scientist, Climate Campaign
INSTITUTION: Union of Concerned Scientists
DATE: 30 April 2013

NAME: Tadashi Fukami
POSITION: Assistant Professor of Biology
INSTITUTION: Stanford University
DATE: May 21, 2013

NAME: Dr Richard Fuller
POSITION: Senior Lecturer
INSTITUTION: University of Queensland
DATE: 27th April 2013

G

NAME: Eric Galbraith
POSITION: Assistant Professor
INSTITUTION: Department of Earth and Planetary Science, McGill University
DATE: April 29, 2013

NAME: Candace Galen
POSITION: Professor
INSTITUTION: University of Missouri
DATE: April 26,2013

NAME: Amiran Gamkrelidze MD, PhD, Professor
POSITION: Director General
INSTITUTION: National Center for Disease Control and Public Health, Tbilisi
DATE: 18 May 2013

NAME: Laura Gangoso
POSITION: Post doc researcher
INSTITUTION: Department of Wetland Ecology, Estación Biológica de Doñana, CSIC, Spain.
DATE: 25/04/2013

NAME: Francisco Garcia-Gonzalez
POSITION: Ramon y Cajal Research Fellow
INSTITUTION: Donana Biological Station-Spanish Research Council, Seville, Spain
DATE: 25th April 2013

NAME: Christopher Gardner, PhD
POSITION: Associate Professor of Medicine (Research)
INSTITUTION: Stanford Prevention Research Center, Stanford University
DATE: May 20, 2013

NAME: Stephen Garnett
POSITION: Professor of Conservation and Sustainable Livelihoods
INSTITUTION: Charles Darwin University
DATE: 25 April 2013

NAME: Dan Gavin
POSITION: Associate Professor, Department of Geography
INSTITUTION: University of Oregon
DATE: May 6, 2013

NAME: Leah Gerber
POSITION: Associate Professor
INSTITUTION: School of Life Sciences, Arizona State University
DATE: April 25, 2013

NAME: Anne E. Giblin
POSITION: Senior Scientist
INSTITUTION: Marine Biological Laboratory
DATE: 4/29/2013

NAME: Diego Gil
POSITION: Senior Scientist
INSTITUTION: MNCN (CSIC, Spain)
DATE: 25-4-13

NAME: Michael Gillings
POSITION: Professor of Molecular Evolution
INSTITUTION: Biological Sciences, Macquarie University, Sydney, Australia
DATE: 28/04/2013

NAME: Dr. Peter Gleick
POSITION: Pacific Institute, President
Member, US National Academy of Sciences
INSTITUTION: Pacific Institute
DATE: May 8, 2013

NAME: Deborah M. Gordon
POSITION: Professor
INSTITUTION: Stanford University
DATE: 5-16-13

NAME: Lisa J. Graumlich
POSITION: Dean, College of the Environment
Virginia and Prentice Bloedel Professor
INSTITUTION: University of Washington
DATE: April 26, 2012

NAME: ANDREW GREEN
POSITION: RESEARCH PROFESSOR
INSTITUTION: DOÑANA BIOLOGICAL STATION
DATE: 30 APRIL 2013

NAME: Charles H. Greene
POSITION: Professor, Department of Wrath & Atmospheric Sciences
INSTITUTION: Cornell University
DATE: 4/30/13

NAME: Harry W. Greene
POSITION: Professor of Ecology and Evolutionary Biology
INSTITUTION: Cornell University
DATE: April 28, 2013

NAME: Dr Merilyn J Grey
POSITION: Honorary Research Fellow
INSTITUTION: Department of Zoology, La Trobe University, Melbourne, Australia
DATE: 20 May 2013

NAME: Marianna Grossman
POSITION: President and Executive Director
INSTITUTION: Sustainable Silicon Valley
DATE: MAY 3, 2013

NAME: Mats Gyllenberg
POSITION: Professor, Head of Department
INSTITUTION: Department of Mathematics and Statistics, University of Helsinki
DATE: May 7, 2013

H

NAME: Elizabeth A. Hadly
POSITION: Professor, Department of Biology and Senior Fellow, Woods Institute
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: Joan Stephens Hadly
POSITION: Sr Vice President, Advancement
INSTITUTION: Museum of Science Boston
DATE: May 8, 2013

NAME: Yohannes Haile-Selassie
POSITION: Curator
INSTITUTION: Cleveland Museum of Natural History
DATE: May 12, 2013

NAME: Sharon J. Hall
POSITION: Associate Professor
INSTITUTION: Arizona State University
DATE: May 18, 2013

NAME: Olivier Hamant
POSITION: Researcher
INSTITUTION: INRA, France
DATE: 26 April 2013

NAME: Philip C. Hanawalt
POSITION: Morris Herzstein Professor of Biology
INSTITUTION: Stanford University
DATE: May 16, 2013

NAME: Catherine HÄNNI
POSITION: CNRS Director
INSTITUTION: CNRS/ENS Lyon
DATE: April 30, 2013

NAME: James Hansen
POSITION: Director of Hansen Climate Science Program
INSTITUTION: Columbia University Earth Institute
DATE: 21 May 2013

NAME: Ilkka Hanski
POSITION: Research professor
INSTITUTION: University of Helsinki
DATE: April 25, 2013

NAME: David D. Hart
POSITION: Director, Senator George J. Mitchell Center for Sustainability Solutions
INSTITUTION: University of Maine, Orono
DATE: 4/30/2013

NAME: John Harte
POSITION: Professor of Ecosystem Sciences
INSTITUTION: UC Berkeley
DATE: April 25, 2013

NAME: Celia A. Harvey
POSITION:Vice President, Ecosystem Services,
INSTITUTION: Conservation International
DATE: May 21, 2013

NAME: PAUL HARVEY CBE FRS
POSITION: Professor
INSTITUTION: Department of Zoology, University of Oxford, UK
DATE: 7 May 2013

NAME: Angie Haslem
POSITION: Research Fellow
INSTITUTION: La Trobe University
DATE: 20 May 2013

NAME: AHMED HASSANALI
POSITION: Professor of Chemistry (Chemical Ecology & Bioprospecting)
INSTITUTION: Kenyatta University, Nairobi, KENYA
DATE: May 20, 2013

NAME: Alan Hastings
POSITION: Distinguished Professor
INSTITUTION:University of California, Davis
DATE: May 17, 2013

NAME: MARK HAY
POSITION: PROFESSOR OF BIOLOGY
INSTITUTION: GEORGIA INSTITUTE OF TECHNOLOGY
DATE: 4/25/13

NAME: Harold Heatwole
POSITION: Professor of Biology
INSTITUTION: North Carolina State University
DATE: 25 April 2013

NAME: H. Craig Heller
POSITION: Professor of Biology and Human Biology
INSTITUTION: Stanford University
DATE: May16, 2013

NAME: Jessica J. Hellmann
POSITION: Associate Professor of Biological Sciences
INSTITUTION: University of Notre Dame
DATE: May 15, 2013

NAME: Martin Hellman
POSITION: Professor Emeritus of Electrical Engineering
INSTITUTION: Stanford University
DATE: 26 APRIL 2013

NAME: Hans R Herren
POSITION: President
INSTITUTION: Millennium Institute, Washington, DC and Biovision Foundation, Zurich
DATE: May 10, 2013

NAME: Josiah Heyman
POSITION: Professor of Anthropology and Chair, Sociology and Anthropology
INSTITUTION: University of Texas at El Paso
DATE: April 29, 2013

NAME: Thomas Hickler
POSITION: Professor for Quantitative Biogeography
INSTITUTION: Biodiversity and Climate Research Centre (BiK-F), Frankfurt/Main, Germany
DATE: 17.5.2013

NAME: Larry D. Hinzman
POSITION: Director and Professor
INSTITUTION: University of Alaska Fairbanks
DATE: 20 May 2013

NAME: Mark Hixon
POSITION: Hsiao Endowed Chair of Marine Biology
INSTITUTION: University of Hawai'i at Manoa
DATE: 25 April 2013

NAME: Leslea J. Hlusko
POSITION: Associate Professor Integrative Biology
INSTITUTION: University of California Berkeley
DATE: 13 May 2013

NAME: Prof Richard J Hobbs
POSITION: Australian Laureate Fellow School of Plant Biology
INSTITUTION: The University of Western Australia
DATE: 20 May 2013

NAME: Dr. Karen E. Hodges
POSITION: Associate Professor, Conservation Biology
INSTITUTION: University of British Columbia Okanagan, Kelowna, BC, Canada
DATE: 25 April 2013

NAME: Hopi E. Hoekstra
POSITION: Alexander Agassiz Professor of Zoology
INSTITUTION: Harvard University
DATE: April 25, 2013

NAME: Christian Hof
POSITION: Postdoctoral Researcher
INSTITUTION: Biodiversity and Climate Research Centre (BiK-F) & Senckenberg Gesellschaft für Naturforschung, Frankfurt, Germany
DATE: 17 May 2013

NAME: Andrew J. Hoffman
POSITION: School of Natural Resources & Environment/Ross School of Business
INSTITUTION: University of Michigan
DATE: April 25, 2013

NAME: Karen D. Holl
POSITION: Professor of Environmental Studies
INSTITUTION: University of California, Santa Cruz
DATE: 25 April 2013

NAME: C.S.Holling
POSITION: Emeritus Professor
INSTITUTION: University of Florida
DATE: May 20, 2003

NAME: Professor Joseph A M Holtum
POSITION: Coordinator of Plant Sciences and Tropical Agriculture
INSTITUTION: James Cook University
DATE: Monday 20th May 2013

NAME: David Hooper
POSITION: Professor of Biology
INSTITUTION: Western Washington University, Bellingham, WA
DATE: 5/19/13

NAME: Professor Stephen D. Hopper AC FLS FTSE
POSITION: Professor of Biodiversity
INSTITUTION: The University of Western Australia
DATE: 26th April 2013

NAME: Joaquín Hortal
POSITION: RyC Research Fellow

INSTITUTION: Museo Nacional de Ciencias Naturales (CSIC), Madrid, Spain
DATE: 13 May 2013

NAME: Øystein Hov
POSITION: Director of Research and Professor
INSTITUTION: Norwegian Meteorological Institute and University of Oslo
DATE: 20 May 2013

NAME: Alex Hubbe
POSITION: Postdoctoral Fellow
INSTITUTION: Instituto de Biociências, Universidade de São Paulo, Brazil
DATE: 05/09/2013

NAME: Prof. Lesley Hughes
POSITION: Dept of Biological Sciences
INSTITUTION: Macquarie University NSW, Australia
DATE: 28 April 2013

NAME: Jeffrey A. Hutchings
POSITION: Professor
INSTITUTION: Department of Biology, Dalhousie University,CANADA, and Centre for Ecological and Evolutionary Synthesis, University of Oslo, NORWAY
DATE: April 25, 2013

I

NAME: Rolf A. Ims
POSITION: Professor of Ecology
INSTITUTION: Department of Arctic and Marine Biology, University of Tromsø, Norway
DATE: May 3, 2013

NAME: Brian Inouye
POSITION: Associate Professor
INSTITUTION: Florida State University
DATE: April 25, 2013

NAME: David W. Inouye
POSITION: Professor
INSTITUTION: University of Maryland
DATE: 25 April 2013

J

NAME: Nina G. Jablonski
POSITION: Distinguished Professor of Anthropology
INSTITUTION: The Pennsylvania State University
DATE: May 4, 2013

NAME: Wes Jackson
POSITION: President
INSTITUTION: The Land Institute
DATE: April 30, 2013

NAME: A. Hope Jahren
POSITION: Professor of Geobiology
INSTITUTION: University of Hawaii at Manoa
DATE: April 29, 2013

NAME: Fabian M Jaksic
POSITION: Professor
INSTITUTION: Universidad Catolica de Chile
DATE: April 28, 2013

NAME: Marco A. Janssen
POSITION: Associate Professor
INSTITUTION: School of Human Evolution and Social Change, Arizona State University
DATE: April 25, 2013

NAME: Ivan Janssens
POSITION: Professor
INSTITUTION: Biology Department, University Of Antwerp, Belgium
DATE: 19/05/13

NAME: Daniel H. Janzen
POSITION: Professor of Conservation Biology
INSTITUTION: University of Pennsylvania
DATE: 26 April 2013

NAME: Dr. Christopher B Jones
POSITION: Faculty
INSTITUTION: School of Public Policy and Administration, Walden University
DATE: Apr 26, 2013

NAME: James Holland Jones
POSITION: Associate Professor of Anthropology and Senior Fellow, Woods Institute for the Environment
INSTITUTION: Stanford University
DATE: 18 May 2013

NAME: Jeremy B. Jones
POSITION: Professor of Biology
INSTITUTION: University of Alaska Fairbanks
DATE: May 19, 2013

NAME: Patricia P. Jones, Ph.D.
POSITION: Professor of Biology
INSTITUTION: Stanford University
DATE: May 17, 2013

NAME: William Jury
POSITION: Emeritus Distinguished Professor of Soil Physics
INSTITUTION: UC Riverside
DATE: 4/25/2013

K

NAME: Dr Jules Kajtar
POSITION: Research Associate
INSTITUTION: Climate Change Research Centre, University of New South Wales, Australia
DATE: 29/04/13

NAME: Dibesh Karmacharya
POSITION: International Director
INSTITUTION: Center for Molecular Dynamics Nepal
DATE: May 8, 2013

NAME: David Karoly
POSITION: Professor of Climate Science
INSTITUTION: University of Melbourne
DATE: April 29, 2013

NAME: Daniel Karp
POSITION: Postdoctoral Scholar
INSTITUTION: University of California, Berkeley and The Nature Conservancy
DATE: 4/25/2013

NAME: Shakkie Kativu
POSITION: Professor
INSTITUTION: University of Zimbabwe
DATE: 17 May 2013

NAME: LILIANA KATINAS
POSITION: PROFESSOR OF PLANT MORPHOLOGY
INSTITUTION: UNIVERSIDAD NACIONAL DE LA PLATA, ARGENTINA
DATE: MAY 19, 2013

NAME: Donald Kennedy
POSITION: President Emeritus and Bing Professor of Environmental Science, Emeritus; Editor-in-Chief, Science, 2000 to 2008
INSTITUTION: Stanford University
DATE: April 25, 2013

NAME: Julie Kennedy
POSITION: Professor (Teaching), Environmental Earth System Science
INSTITUTION: Stanford University
DATE: May 21, 2013

NAME: Thomas Kiørboe
POSITION: Professor, Centre Leader
INSTITUTION: Centre for Ocean Life, National Institute of Aquatic Resources, Technical University of Denmark
DATE: May 15, 2013

NAME: Patrick V. Kirch
POSITION: Class of 1954 Professor of Anthropology and Integrative Biology
INSTITUTION: University of California, Berkeley
DATE: 29 April 2013

NAME: James Barrie Kirkpatrick
POSITION: Distinguished Professor of Geography and Environmental Studies
INSTITUTION: University of Tasmania
DATE: 26/4/2013

NAME: Professor Roger Kitching AM
POSITION: Chair of Ecology

INSTITUTION: Griffith University, Brisbane
DATE: 26.4.2010

NAME: Alan K. Knapp
POSITION: Professor of Biology
INSTITUTION: Colorado State University
DATE: April 25, 2013

NAME: Andrew H. Knoll
POSITION: Fisher Professor of Natural History
INSTITUTION: Harvard University
DATE: April 30, 2013

NAME: Matthew L. Knope
POSITION: Post-doctoral research fellow
INSTITUTION: Dept. of Geological and Environmental Sciences, Stanford University
DATE: April 25, 2013

NAME: Jacob Koella
POSITION: Professor
INSTITUTION: University of Neuchatel
DATE: 4/30/2013

NAME: Jeffrey R Koseff
POSITION: William A Campbell and Martha Campbell Professor of Engineering
INSTITUTION: Stanford University
DATE: May 16 2013

NAME: Dr Tineke Kraaij
POSITION: Scientist: Fynbos Ecology
INSTITUTION: South African National Parks
DATE: 10 May 2013

NAME: Nathan Kraft
POSITION: Assistant Professor
INSTITUTION: Department of Biology, University of Maryland College Park
DATE: 5/7/2013

NAME: Holger Kreft
POSITION: Professor
INSTITUTION: Faculty of Forest Sciences and Forest Ecology, University of Gottingen
DATE: May 17 2013

NAME: Claire Kremen
POSITION: Professor
INSTITUTION: University of California, Berkeley
DATE: 4/25/13

NAME: Andrew Krockenberger
POSITION: Professor and Dean of Research
INSTITUTION: James Cook University
DATE: 20th May 2013

NAME: Markku Kulmala
POSITION: Academy Professor
INSTITUTION: University of Helsinki, Department of Physics
DATE: 2.5. 2013

NAME:Juri Kurhinen
POSITION: researcher, Helsinki University
INSTITUTION: koordinator of the international project
DATE:02.05.2013

NAME: Thomas A. Kursar
POSITION: Professor
INSTITUTION: University of Utah (Dept of Biology)
DATE: 27 April, 2013

L

NAME: Eric Lambin
POSITION: Professor
INSTITUTION: Stanford University and Université catholique de Louvain
DATE: May 18, 2013

NAME: Dr. Tomás Landete-Castillejos
POSITION: Vice-director of IREC (Spain's national game institute); Vicepresident of FEDFA (European Federation of Deer Farmers Associations; www.fedfa.es); founder of science-based companies: European Meeting on Antlers and Deer International Scientific Training S.L. (www.emad.es); Venadogen (www.venadogen.com).
INSTITUTION: University of Castilla-La Mancha
DATE: May 7th 2013

NAME: John Largier
POSITION: Professor of Oceanography
INSTITUTION: University of California Davis
DATE: 5 May 2013

NAME: William F. Laurance
POSITION: Distinguished Research Professor & Australian Laureate
INSTITUTION: James Cook University, Cairns, Queensland, Australia
DATE: 20 May 2013

NAME: Beverly E. Law
POSITION: Professor Global Change Biology & Terrestrial Systems Science
INSTITUTION: Department of Forest Ecosystems & Society, Oregon State University
DATE: May 10, 2013

NAME: Prof. Mike Lawes
POSITION: Professor, Savanna Management and Wildlife Conservation, Research Institute For The Environment And Livelihoods
INSTITUTION: Charles Darwin University
Darwin, Northern Territory 0909, AUSTRALIA
DATE: 26 April 3013

NAME: Dr Susan Lawler
POSITION: Head of Department of Environmental Management and Ecology
INSTITUTION: La Trobe Universtiy, Wodonga, Victoria, Australia
DATE: 20 May 2013

NAME: Stephanie Lawson
POSITION: Professor of Politics and International Relations
INSTITUTION: Macquarie University, Sydney, NSW, Australia
DATE: 1 May 2013

NAME: Yvon LE MAHO
POSITION: Director of Research
INSTITUTION: Institut Pluridisciplinaire Hubert Curien, CNRS and University of Strasbourg, France
DATE: May 10, 2013.

NAME: Raphael Leblois
POSITION: researcher
INSTITUTION: INRA (French National Institute for Agronomic Research), Lab "Center for Biology and Population Managment", CBGP, Montpellier, France
DATE: 4th of May, 2013

NAME: Herwig Leirs
POSITION: Professor, Evolutionary Ecology Group and Dean, Faculty of Sciences
INSTITUTION: University of Antwerp, Belgium
DATE: 17 may 2013

NAME: Yuri L. R. Leite
POSITION: Associate Professor
INSTITUTION: Universidade Federal do Espirito Santo, Brazil
DATE: 17 May 2013

NAME: Jennifer Leonard
POSITION: permanent researcher
INSTITUTION: Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas
DATE: April 25, 2013

NAME: Estella B. Leopold
POSITION: Professor Emeritus, Department of Biology
INSTITUTION: University of Washington
DATE: April 23, 2013

NAME: Simon Levin
POSITION: Professor
INSTITUTION: Princeton University
DATE: April 25, 2013

NAME: William Z. Lidicker, Jr.
POSITION: Professor of Integrative Biology Emeritus
INSTITUTION: University of California,

Berkeley
DATE: 29 April 2013

NAME: Kent Lightfoot
POSITION: Professor, Department of Anthropology
INSTITUTION: UC Berkeley
DATE: May 8, 2013

NAME: MAURICIO LIMA
POSITION: FULL PROFESSOR
INSTITUTION: DEPARTAMENTO DE ECOLOGÍA, FACULTAD DE CIENCIAS BIOLÓGICAS, PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
DATE: 25/04/2013

NAME: Ken Lindeman
POSITION: Professor, Sustainability Program Chair
INSTITUTION: Florida Institute of Technology
DATE: April 27, 2013

NAME: Richard L. Lindroth
POSITION: Professor and Associate Dean for Research
INSTITUTION: University of Wisconsin-Madison
DATE: April 29, 2013

NAME: Lee Hsiang Liow
POSITION: Researcher
INSTITUTION: Centre for Ecological and Evolutionary Synthesis, Department of Biosciences, University of Oslo, Oslo, Norway
DATE: 25 April 2013

NAME: Jere H. Lipps
POSITION: Professor Emeritus
INSTITUTION: University of California, Berkeley
DATE: April 29, 2013

NAME: Professor Adrian M Lister
POSITION: Research Leader
INSTITUTION: The Natural History Museum, London
DATE: 13th May 2013

NAME: Jianguo (Jack) Liu
POSITION: Rachel Carson Chair in Sustainability and Director
INSTITUTION: Center for Systems Integration and Sustainability, Michigan State University
DATE: 4/26/13

NAME: Dr John Llewelyn
POSITION: Postdoctoral research fellow
INSTITUTION: James Cook University, Australia
DATE: 20/5/2013

NAME: Jorge Miguel Lobo
POSITION: Research professor of the Museo Nacional de Ciencias Naturales (CSIC)
INSTITUTION: Museo Nacional de Ciencias Naturales (CSIC). C/ Jose Gutiérrez Abascal 2. Madrid
DATE:13 May 2013

NAME: Michael E. Loik
POSITION: Associate Professor, Department of Environmental Studies
INSTITUTION: University of California, Santa Cruz
DATE: April 25, 2013

NAME: Adam Lomnicki
POSITION: Professor Emeritus of Biology
INSTITUTION: Institute of Environmental Scieces, Jagiellonian University, Krakow, Poland
DATE: 18th of May 2013

NAME: John Longino
POSITION: Professor
INSTITUTION: Department of Biology, University of Utah
DATE: 26 April 2013

NAME: Cindy V. Looy
POSITION: Assistant Professor
INSTITUTION: UC Berkeley and UC Museum of Paleontology
DATE: April 29, 2013

NAME: Celia López-González
POSITION: Profesor Titular
CIIDIR Unidad Durango
INSTITUTION: Instituto Politécnico Nacional
DATE: May 10 2013

NAME: Jonathan Losos
POSITION: Professor and Curator
INSTITUTION: Dept of Organismic and Evolutionary Biology and Museum of Comparative Zoology, Harvard University
DATE: April 28, 2013

NAME: Thomas E. Lovejoy
POSITION: University Professor
INSTITUTION: George Mason University
DATE: April 25, 2013

NAME: Richard Loyn
POSITION: Ecologist; Director, Eco Insights, and recently Principal Scientist, Arthur Rylah Institute for Environmental Research (Victorian Government)
INSTITUTION: Eco Insights (also research fellow at La Trobe Unviversity; honorary senior Fellow at University of Melbourne & Charles Sturt University)
DATE: 8 May 2013

NAME: Stephen Luby
POSITION: Professor or Medicine
INSTITUTION: Stanford University
DATE: April 29, 2013

NAME: Gary Luck
POSITION: Professor in Ecology and Interdisciplinary Science
INSTITUTION: Charles Sturt University, Institute for Land, Water and Society
DATE: 19th May 2013

NAME: Per Lundberg
POSITION: Professor
INSTITUTION: Dept. Biology, Lund University, Lund, Sweden
DATE: 30 April, 2013

NAME: Ian D. Lunt
POSITION: Associate Professor in Vegetation Ecology & Management
INSTITUTION: Institute for Land, Water & Society, Charles Sturt University, Australia
DATE: 20 May 2013

M

NAME: Manuel Maass
POSITION: Research Scientist
INSTITUTION: Centro de Investigaciones en Ecosistemas (CIEco), Universidad Nacional Autónoma de México (UNAM)
DATE: April 27, 2013

NAME: Georgina Mace
POSITION: Professor of Biodiversity and Ecosystems
INSTITUTION: University College London
DATE: 10 May 2013

NAME: James A. MacMahon
POSITION: Dean, College of Science
INSTITUTION: Utah State University
DATE: 25 April 2013

NAME: Adjunct Prof Jonathan Majer
POSITION: Recently retired as Professor of Invertebrate Conservation
INSTITUTION: Curtin University, Perth, Western Australia
DATE: 26/Apr/13

NAME: Stephanie A. Malin, Ph.D.
POSITION: Mellon Foundation Postdoctoral Fellow with Center for Environmental Studies and Superfund Research Program
INSTITUTION: Brown University
DATE: 26 April 2013

NAME: Michael A. Mallin
POSITION: Research Professor
INSTITUTION: Center for Marine Science, University of North Carolina Wilmington
DATE: April 25, 2013

NAME: Michael E. Mann
POSITION: Distinguished Professor of Meteorology; Director of Penn State Earth System Science Center

INSTITUTION: Pennsylvania State University
DATE: May 18, 2013

NAME: W. Andrew Marcus
POSITION: Professor of Geography & Associate Dean, Social Sciences
INSTITUTION: University of Oregon
DATE: April 29, 2013

NAME: Dr Martine Maron
POSITION: Senior Lecturer in Environmental Management
INSTITUTION: The University of Queensland
DATE: 10 May 2013

NAME: Pablo Marquet
POSITION: Full Professor of Ecology
INSTITUTION: Pontificia Universidad Catolica de Chile
DATE: April 28, 2013

NAME: Jason P. Marshal
POSITION: Senior Lecturer of Ecology
INSTITUTION: University of the Witwatersrand
DATE: 9 May 2013

NAME: Richard A. Marston
POSITION: University Distinguished Professor
INSTITUTION: Kansas State University
DATE: 30 April 2013

NAME: Airam Rodríguez Martín
POSITION: Postdoctoral Researcher
INSTITUTION: Estación Biológica de Doñana CSIC
DATE: 25 April 2013

NAME: Jean-Noël Martinez
POSITION: Professor of Geology and Director of the Paleontological Institute at the National University of Piura
INSTITUTION: National University of Piura - Peru
DATE: 17th May 2013

NAME: Enrique Martínez-Meyer
POSITION: Researcher
INSTITUTION: Instituto de Biología, Universidad Nacional Autónoma de México
DATE: May 10, 2013

NAME: Gil Masters
POSITION: Professor (Emeritus)
INSTITUTION: Civil and Environmental Engineering Department, Stanford University
DATE: May 20, 2013

NAME: Damon Matthews
POSITION: Associate Professor
INSTITUTION: Concordia University, Montreal, Canada
DATE: April 29, 2013

NAME: Erik Matthysen
POSITION: Professor, Evolutionary Ecology Group
INSTITUTION: University of Antwerp, Belgium
DATE: 17 May 2013

NAME: Kevin McCann
POSITION: Canadian Research Chair in Biodiversity
INSTITUTION: University of Guelph
DATE: May 13, 2013

NAME: Perry L. McCarty
POSITION: Silas H. Palmer Professor Emeritus, Environmental Engineering
INSTITUTION: Stanford Universitiy
DATE: May 20, 2013

NAME: Susan K. McConnell, Ph.D.
POSITION: Susan B. Ford Professor
INSTITUTION: Stanford University
DATE: May 16, 2013

NAME: Michael McGehee
POSITION: Associate Professor of Materials Science and Engineering
INSTITUTION: Stanford University
DATE: May 20, 2013

NAME: Dr. Peter B. McIntyre
POSITION: Assistant Professor
INSTITUTION: University of Wisconsin
DATE: 26 April 2013

NAME: Galen A. McKinley
POSITION: Associate Professor of Atmospheric and Oceanic Sciences; Faculty Affiliate, Center for Climatic Research, Nelson Institute for Environmental Studies
INSTITUTION: University of Wisconsin - Madison
DATE: May 1, 2013

NAME: Sarah McMenamin
POSITION: Postdoctoral Researcher
INSTITUTION: University of Washington
DATE: April 25, 2013

NAME: Rodrigo A. Medellin
POSITION: Senior Professor of Ecology
INSTITUTION: National Autonomous University of Mexico
DATE: April 25, 2013

NAME: Timothy D. Meehan
POSITION: Associate Scientist
INSTITUTION: Wisconsin Energy Institute, University of Wisconsin-Madison
DATE: 29 May 2013

NAME: Katrin Meissner
POSITION: Associate Professor
INSTITUTION: University of New South Wales
DATE: 29.04.2013

NAME: Natalia Gañán Mejías
POSITION: Postdoctoral researcher
INSTITUTION: Unaffiliated
DATE: 26/04/2013

NAME: David J. Meltzer
POSITION: Henderson-Morrison Professor of Prehistory
INSTITUTION: Southern Methodist University
DATE: May 13, 2013

NAME: Sarah Keene Meltzoff
POSITION: Associate Professor
INSTITUTION: Rosenstiel School of Marine and Atmospheric Science, University of Miami
DATE: 28 April 2013

NAME: Santiago Merino
POSITION: Professor of Research
INSTITUTION: Higher Council for Scientific Research (CSIC-SPAIN)
DATE: 25-04-2013

NAME: Laura A. Meyerson
POSITION: Associate Professor
INSTITUTION: University of Rhode Island
DATE: May 2, 2013

NAME: Fiorenza Micheli
POSITION: Professor
INSTITUTION: Stanford University, Hopkins Marine Station
DATE: 25 April 2013

NAME: Edward L. Miles
POSITION: Professor Emeritus of Marine Studies and Public Affairs, School of Marine Studies and Environmental Affairs
INSTITUTION: University of Washington
DATE: May 3, 2013

NAME: Brian Miller, Ph.D.
POSITION: Senior Scientist
INSTITUTION: Wind River Ranch Foundation, PO Box 27, Watrous NM 87753
DATE: April 25, 2013

NAME: L. Scott Mills
POSITION: Professor
INSTITUTION: Department of Ecosystem and Conservation Sciences, University of Montana
DATE: May 3, 2013

NAME: Professor Bruce Milthorpe
POSITION: Dean of Science
INSTITUTION: University of Technology Sydney
DATE: 1 May 2013

NAME: David P. Mindell
POSITION: Visiting Professor
INSTITUTION: University of California, San Francisco
DATE: 25 April 2013

NAME: Brent D. Mishler
POSITION: Professor of Integrative Biology, Director of the University and Jepson Herbaria
INSTITUTION: University of California, Berkeley
DATE: April 29, 2013

NAME: Cary J. Mock
POSITION: Professor of Geography
INSTITUTION: University of South Carolina, Columbia
DATE: 5/13/2013

NAME: Atte Moilanen
POSITION: Professor, Conservation Decision Analysis
INSTITUTION: University of Helsinki, Dept. Biosciences
DATE: April 25, 2013

NAME: David R. Montgomery
POSITION: Professor (Geomorphology)
INSTITUTION: University of Washington
DATE: 5/7/13

NAME: Arne O. Mooers
POSITION: Professor of Biodiversity
INSTITUTION: SImon Fraser University, Canada
DATE: April 25, 2013

NAME: Harold A. Mooney
POSITION: Professor Emeritus, Department of Biology, and Senior Fellow, Woods Institute
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: MORAND Serge
POSITION: DR CNRS, Université de Montpellier 2
INSTITUTION: CNRS (Centre National de la Rercherche, France)
DATE: 02/06/2013

NAME: Juan Moreno
POSITION: Research Professor CSIC (Spanish Council for Scientific Research)
INSTITUTION: Department of Evolutionary Ecology, National Museum
of Natural Sciences (CSIC), Madrid, Spain
DATE: 26 April 2013

NAME: Christopher Moy
POSITION: Lecturer
INSTITUTION: University of Otago,
New Zealand
DATE: May 19, 2013

NAME: Prof. Dr. Andreas Mulch
POSITION: Vice Director Biodiversity and Climate Research Centre Frankfurt
INSTITUTION: Biodiversity and Climate Research Centre Frankfurt
DATE: 17.05.2013

NAME: Geoffrey Mwachala
POSITION: Director of Collections and Research
INSTITUTION: National Museums of Kenya
DATE: 20 June 2013

NAME: John Peterson Myers
POSITION: CEO and Chief Scientist
INSTITUTION: Environmental Health Sciences, Charlottesville, Virginia
DATE: April 23, 2013

NAME: Atle Mysterud
POSITION: Professor
INSTITUTION: University of Oslo, Norway
DATE: 25. April 2013

N

NAME: Nalini Nadkarni
POSITION: Full Professor, Dept of Biology, and Director,
Center for Science and Mathematics Education
INSTITUTION: University of Utah
DATE: April 26, 2013

NAME: Shahid Naeem
POSITION: Professor of Ecology
INSTITUTION: Columbia University
DATE: 25 April 2013

NAME: Tohru Nakashizuka
POSITION: Professor
INSTITUTION: Graduate School of Life Sciences, Tohoku University
DATE: May 7, 2013.

NAME: Rosamond L. Naylor
POSITION: Director, Program on Food Security and the Environment and Professor, Department of Environmental Earth System Science
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: Ioan Negrutiu
POSITION: Professor biology
INSTITUTION: ENS Lyon, Michel Serres Institute
DATE: April 25, 2013

NAME: Tarique Niazi
POSITION: Associate Professor of Environmental Sociology
INSTITUTION: University of Wisconsin-Eau Claire
DATE: May 2, 2013

NAME: GRACIELA G. NICOLA
POSITION: FULL PROFESSOR
INSTITUTION: UNIVERSITY OF CASTILLA-LA MANCHA (UCLM), SPAIN
DATE: 29/04/2013

NAME: Prof. Dr. Manfred Niekisch
POSITION: University Professor and Zoo Director
INSTITUTION: Goethe University and Frankfurt Zoo
DATE: 17. May 2013

NAME: Rasmus Nielsen
POSITION: Professor
INSTITUTION: University of California - Berkeley
DATE: April 29 2013

NAME: Dale G. Nimmo
POSITION: Research Fellow
INSTITUTION: Deakin University, Australia
DATE: 20-05-2012

NAME: DAVID NOGUÉS-BRAVO
POSITION: ASSOCIATE PROFESSOR
INSTITUTION: UNIVERSITY OF COPENHAGEN
DATE: 25-APRIL-2013

NAME: NORET Nausicaa
POSITION: ASSISTANT PROFESSOR
INSTITUTION: UNIVERSITE LIBRE DE BRUXELLES
DATE: 30 04 2013

NAME: Christopher M. Nyamai
POSITION: Senior Lecturer, Chair, Department of Geology
INSTITUTION: University of Nairobi DATE: 15th May 2013

O

NAME: Karen Oberhauser
POSITION: Professor
INSTITUTION: University of Minnesota
DATE: 4/29/2013

NAME: Timothy G. O'Connor
POSITION: Observation Scientist (plus Honorary Professor, School of Animal, Plant and Environmental Sciences)
INSTITUTION: South African Environmental Observation Network, PO Box 2600, Pretoria 0001, South Africa (University of the Witwatersrand, Johannesburg, South Africa)
DATE: 20 May 2013

NAME: John C. Ogden
POSITION: Emeritus Professor
INSTITUTION: University of South Florida (USF)
DATE: April 30, 2013

NAME: Onesmo K. ole-MoiYoi MD, DSc (hc), EBS (Kenya)

POSITION: Chair Board of Management
INSTITUTION: Kenya Agricultural Research Institute
DATE: 14 May 2013

NAME: Gordon H. Orians
POSITION: Professor Emeritus of Biology
INSTITUTION: University of Washington, Seattle, WA 98195
DATE: April 25, 2013

NAME: Dr. Jamie F Orr
POSITION: Adjunct Faculty, Physics & Engineering, Foothill College & Faculty Researcher, NASA Ames Research Center
INSTITUTION: Foothill College and NASA Ames Research Center
DATE: May 15, 2013

NAME: John Orrock
POSITION: Assistant Professor
INSTITUTION: Department of Zoology, University of Wisconsin-Madison
DATE: April 30, 2013

NAME: Otso Ovaskainen
POSITION: Professor
INSTITUTION: University of Helsinki, Finland
DATE: April 25th 2013

NAME: Norman Owen-Smith
POSITION: Emeritus Research Professor
INSTITUTION: University of the Witwatersrand, Johannesburg
DATE: May 9, 2013

P

NAME: LUIS F. PACHECO
POSITION: PROFESSOR AND RESEARCHER
INSTITUTION: INSTITUTO DE ECOLOGÍA, UNIVERSIDAD MAYOR DE SAN ANDRÉS, LA PAZ, BOLIVIA
DATE: 24 APRIL, 2013

NAME: Kevin Padian
POSITION: Professor and Curator
INSTITUTION: University of California, Berkeley
DATE: 4/29/2013

NAME: Dianna K Padilla
POSITION: Professor, Department of Ecology and Evolution
INSTITUTION: Stony Brook University
DATE: April 25 2013

NAME: Stephen Palumbi
POSITION: Professor, Department of Biology and Director, Hopkins Marine Station
INSTITUTION: Stanford University
DATE: April 23, 2013

NAME: John M. Pandolfi
POSITION: Professor
INSTITUTION: University of Queensland, Brisbane, Queensland, AUSTRALIA
DATE: 26 April 2013

NAME: Mario Garcia Paris
POSITION: Permanent Researcher (Investigador Científico)
INSTITUTION: MNCN-CSIC (Museo Nacional de Ciencias Naturales-Consejo Superior de Investigaciones Cientificas, Spain)
DATE: 25/April/2013

NAME: James L. Patton, PhD
POSITION: Curator and Professor Emeritus
INSTITUTION: Museum of Vertebrate Zoology and Department of Integrative Biology, University of California, Berkeley
DATE: 25 April 2013

NAME: Daniel Pauly
POSITION: Professor of Fisheries
INSTITUTION: Fisheries Centre, University of British Columbia, Vancouver, Canada
DATE: April 10, 2013

NAME: Jonathan L. Payne
POSITION: Associate Professor
INSTITUTION: Dept. of Geological & Environmental Sciences, Stanford University
DATE: April 28, 2013

NAME: Richard G. Pearson
POSITION: Emeritus Professor
INSTITUTION: James Cook University, Australia
DATE: May 20, 2013

NAME: Kabir G. Peay
POSITION: Assistant Professor
INSTITUTION: Stanford University
DATE: 4/25/2013

NAME: Pablo Pelaez-Campomanes
POSITION: Senior researcher
INSTITUTION: National Museum of Natural Sciences, CSIC, Spain
DATE: 25/04/2013

NAME: Petri Pellikka
POSITION: Professor of Geoinformatics
INSTITUTION: University of Helsinki
DATE: 15.5.2013

NAME: Dr Avril Pereira
POSITION: Research Fellow
INSTITUTION: The Florey Institute of Neuroscience and Mental Health
DATE: 20 May, 2013

NAME: Henrique Miguel Pereira
POSITION: Invited Professor
INSTITUTION: Faculty of Sciences of the University of Lisbon, Portugal
DATE: 13 May 2013

NAME: Melissa Pespeni
POSITION: National Science Foundation Postdoctoral Fellow in Biology
INSTITUTION: Indiana University
DATE: April 25, 2013

NAME: Owen Petchey
POSITION: Professor
INSTITUTION: University of Zurich
DATE: 8th May 2013

NAME: Dmitri Petrov
POSITION: Professor of Biology
INSTITUTION: Stanford University
DATE: 5/20/13

NAME: Ben Phillips
POSITION: Senior Research Fellow
INSTITUTION: Centre for Tropical Biodiversity and Climate Change, James Cook University
DATE: 20 May 2013

NAME: Theunis Piersma
POSITION: Professor of Global Flyway Ecology
INSTITUTION: University of Groningen/Royal Netherlands Institute for Sea Research (NIOZ)
DATE: 18 May 2013

NAME: Stuart Pimm
POSITION: Doris Duke Chair of Conservation
INSTITUTION: Duke University
DATE: 28th April 2013

NAME: Stephanie Pincetl, PhD
POSITION: Adjunct Professor, Director, Center for Sustainable Communities, Institute of the Environment and Sustainability
INSTITUTION: UCLA
DATE: April 26, 2013

NAME: Malin L. Pinsky
POSITION: David H. Smith Conservation Research Fellow
INSTITUTION: Princeton University
DATE: April 24, 2013

NAME: Erica Plambeck
POSITION: Professor of Operations, Information and Technology
INSTITUTION: Stanford Graduate School of Business
DATE: May 18 2013

NAME: P. David Polly
POSITION: Professor
INSTITUTION: Department of Geological Sciences, Indiana University
DATE: 25 April 2013

NAME: Warren P. Porter
POSITION: Professor of Zoology and Professor of Environmental Toxicology
INSTITUTION: University of Wisconsin, Madison
DATE: 25 April 2013

NAME: Hugh Possingham
POSITION: Professor and Centre Director
INSTITUTION: The University of Queensland
DATE: 25 April 2013

NAME: Malcolm Potts
POSITION: Professor, School of Public Health
INSTITUTION: University of California-Berkeley
DATE: April 25, 2013

NAME: Mary E. Power
POSITION: Professor
INSTITUTION: Univ. California, Berkeley
DATE: April 25, 2013

NAME: Daniel Press
POSITION: Olga T. Griswold Professor, Environmental Studies Department and Executive Director, Center for Agroecology and Sustainable Food Systems
INSTITUTION: University of California, Santa Cruz
DATE: April 28, 2013

NAME: Aili Pyhälä
POSITION: Postdoctoral Researcher
INSTITUTION: Department of Biosciences, University of Helsinki
DATE: 25th April 2013

NAME: Dr Graham H. Pyke
POSITION: Distinguished Professor
INSTITUTION: School of the Environment, University of Technology Sydney
DATE: 26 April 2013

Q

R

NAME: Nancy N. Rabalais
POSITION: Executive Director and Professor
INSTITUTION: Louisiana Universities Marine Consortium
DATE: 49 April 2013

NAME: Paul A Racey
POSITION: Co-Chair, IUCN Bat Specialist Group
INSTITUTION: Regius Professor of Natural History (Emeritus), University of Aberdeen. Honorary Visiting Professor, University of Exeter in Cornwall
DATE: 30 April 2013

NAME: Carsten Rahbek
POSITION: Professor
INSTITUTION: Center for Macroecology, Evolution and Climate, University of Copenhagen, Denmark
DATE: 15 May 2013

NAME: Paul B Rainey
POSITION: Distinguished Professor
INSTITUTION: New Zealand Institute for Advanced Study & Max Planck Institute for Evolutionary Biology.
DATE: 20.05.13

NAME: Uma Ramakrishnan
POSITION: Associate Professor
INSTITUTION: National Centre of Biological Sciences, Bangalore, India
DATE: May 11, 2013

NAME: Giovani Ramón
POSITION: Post-graduate student
INSTITUTION: James Cook University
DATE: 20/05/2013

NAME: Dr. Eduardo H. Rapoport
POSITION: Professor Emeritus & Investigador Consejo Nacional Investigaciones Científicas
INSTITUTION: Universidad Nacional del Comahue, Bariloche, Argentina
DATE: MAY 20, 2013

NAME: Daniel J. Rasky
POSITION: Senior Scientist
INSTITUTION: Self
DATE: 5/20/2013

NAME: Prof. Peter H. Raven
POSITION: President Emeritus
INSTITUTION: Missouri Botanical Garden
DATE: May 9, 2013

NAME: RAVIGNÉ Virginie
POSITION: RESEARCHER (permanent position)
INSTITUTION: CIRAD
DATE: 21/05/2013

NAME: Dr. John E. Rawlins
POSITION: Curator of Invertebrate Zoology
INSTITUTION: Carnegie Museum of Natural History
DATE: 1 May 2013

NAME: Dr. Maureen E Raymo
POSITION: Lamont Research Professor and Director Lamont-Doherty Core Repository
INSTITUTION: Lamont-Doherty Earth Observatory of Columbia University
DATE: May 11, 2013

NAME: Harry F. Recher
POSITION: Emeritus Professor
INSTITUTION: Edith Cowan University, School of Natural Sciences, Joondalup, Western Australia, Australia
DATE: 26 April 2013

NAME: Kent H. Redford
POSITION: Principal
INSTITUTION: Archipelago Consulting
DATE: May 19, 2013

NAME: William E. Rees, PhD, FRSC
POSITION: Professor Emeritus
INSTITUTION: University of British Columbia
DATE: 26 April 2013

NAME: Jonathan Rhodes
POSITION: Senior Lecturer
INSTITUTION: The University of Queensland
DATE: 29th April 2013

NAME: Brett R. Riddle
POSITION: Professor
INSTITUTION: University of Nevada Las Vegas
DATE: 26 April 2013

NAME: William J. Ripple
POSITION: Professor
INSTITUTION: Oregon State University
DATE: May 18, 2013

NAME: Euan G. Ritchie
POSITION: Lecturer in ecology
INSTITUTION: Deakin University, Australia
DATE: 18/5/2013

NAME: Annapaola Rizzoli
POSITION: DVM, PhD, Animal Ecology Research Group Leader
INSTITUTION: Research and Innovation Centre, Department of Biodiveristy and Molecular Ecology, Edmund Mach Foundation, San Michele all'Adige (TN), Italy
DATE: 26/04/2013

NAME: Dr Lisa Roberts
POSITION: Visiting Fellow, Environmental Science / Design
INSTITUTION: University of Technology, Sydney
DATE: 29 April 2013

NAME: Heyward G. Robinson
POSITION: Senior Scientist, Applied Optics Laboratory
INSTITUTION: SRI International
DATE: 8 May 2013

NAME: John G. Robinson, Ph.D.
POSITION: Executive Vice President, Conservation and Science
INSTITUTION: Wildlife Conservation Society
DATE: April 25, 2013

NAME: Johan Rockström
POSITION: Professor, Water systems and Global Sustainability; Director, Stockholm Resilience Centre
INSTITUTION: Stockholm University
DATE: April 25, 2013

NAME: Antonio Gonzalez Rodriguez
POSITION: Researcher
INSTITUTION: Universidad Nacional Autonoma de Mexico
DATE: April 27th, 2013

NAME: Klaus Rohde
POSITION: Professor Emeritus
INSTITUTION: University of New England, Armidale, Australia
DATE: 26.4.2013

NAME: Terry L. Root
POSITION: Senior Fellow
INSTITUTION: Stanford University
DATE:8 May 2013

NAME: Helen Rowe
POSITION: Assistant Research Professor
INSTITUTION: School of Life Sciences, Arizona State University
DATE: 4-26-2013

NAME: Lasse Ruokolainen
POSITION: Postdoctoral fellow
INSTITUTION: University of Helsinki
DATE: 26.4.2013

S

NAME: Takashi Saitoh
POSITION: Professor
INSTITUTION: Field Science Center, Hokkaido University, Japan
DATE: May 8, 2013

NAME: Osvaldo Sala
POSITION: Julie A. Wrigley Professor of Life Sciences and Sustainability
INSTITUTION: Arizona State University
DATE: 4/25/2013

NAME: Peter F Sale
POSITION: Assistant Director, Institute for Water, Environment and Health
INSTITUTION: United Nations University
DATE: April 25th 2013

NAME: Benjamin Santer
POSITION: Atmospheric Scientist
INSTITUTION: Lawrence Livermore National Laboratory
DATE: May 18, 2013

NAME: José Sarukhán
POSITION: National Coordinator, and Professor Emeritus, UNAM.
INSTITUTION: Mexican National Commission on Biodiversity (CONABIO) and Institute of Ecology, UNAM
DATE: 19th May, 2013

NAME: Dov Sax
POSITION: Associate Professor of Ecology and Evolutionary Biology, Director-Elect for the Center for Environmental Studies
INSTITUTION: Brown University
DATE: May 10, 2013

NAME: James Schaefer
POSITION: Professor
INSTITUTION: Trent University
DATE: 26 April 2013

NAME: Christoph Scheidegger, Prof. Dr.
POSITION: Senior Scientist and Chair Research Group Biodiversity
INSTITUTION: Swiss Federal Institute for Forest, Snow and Landscape Research, WSL, Zürcherstr. 111, CH-8903 Birmensdorf, Switzerland
DATE: April 30, 2013

NAME: William H. Schlesinger
POSITION: President
INSTITUTION: Cary Institute of Ecosystem Studies
DATE: April 25, 2013

NAME: Jan Schnitzler
POSITION: Postdoctoral Researcher
INSTITUTION: Biodiversity and Climate Research Centre
(BiK-F) & Goethe University, Frankfurt, Germany
DATE: May 17, 2013

NAME: Cagan H. Sekercioglu, Ph.D.
POSITION: Assistant Professor
INSTITUTION: University of Utah Department of Biology
DATE: May 11, 2013

NAME: Heikki Seppä
POSITION: Professor
INSTITUTION: Department of Geosciences and Geography, University of Helsinki, Finland
DATE: May 14, 2013

NAME: Fabrizio Sergio
POSITION: Researcher (permanent post)
INSTITUTION: Estacion Biologica de Donana - Consejo Superior de Investigaciones Cientificas, Seville, Spain
DATE: 25 April 2013

NAME: DAVID SERRANO
POSITION: ASSOCIATE PROFESSOR
INSTITUTION: EBD-CSIC
DATE: 25 April 2013

NAME: ROSS D. SHACHTER
POSITION: ASSOCIATE PROFESSOR
INSTITUTION: STANFORD UNIVERSITY
DATE: MAY 20, 2013

NAME: Michael Shapira
POSITION: Adjunct assistant professor
INSTITUTION: Department of Integrative biology, UC Berkeley
DATE: 4/29/13

NAME: Anne Sheppard
POSITION: Research Assistant
INSTITUTION: School of Life Sciences, University of Warwick, UK.
DATE: 26th April 2013

NAME: Steven Sherwood
POSITION: Professor, Director of the Climate Change Research Centre
INSTITUTION: University of New South Wales
DATE: 1 May 2013

NAME: Richard Shine
POSITION: Professor in Biology
INSTITUTION: University of Sydney
DATE: 26 April 2013

NAME: Candida Shinn
POSITION: post-doctoral researcher
INSTITUTION: IMAR - Instituto do Mar
DATE: 25.4.2013

NAME: Marisa Sicilia
POSITION: Post-doctoral researcher
INSTITUTION: Universidad de Castilla-La Mancha (Spain)
DATE: 13th May 2013

NAME: Fernando Simal
POSITION: Manager, Natural and Historic Resources Unit
INSTITUTION: STINAPA Bonaire
DATE: April 26th, 2013

NAME: Ellen L. Simms
POSITION: Professor, Integrative Biology
INSTITUTION: University of California, Berkeley
DATE: 29 April 2013

NAME: Javier A. Simonetti
POSITION: Professor, Facultad de Ciencias, Universidad de Chile, Chile
INSTITUTION: Facultad de Ciencias, Universidad de Chile
DATE: May 20th, 2013

NAME: Jasper Slingsby
POSITION: Biodiversity Scientist

INSTITUTION: South African Environmental Observation Network
DATE: 10 May 2013

NAME: Adam B. Smith
POSITION: Postdoctoral Researcher
INSTITUTION: Center for Conservation and Sustainable Development, Missouri Botanical Garden
DATE: April 25th, 2013

NAME: Kirk R. Smith
POSITION: Professor of Global Environmental Health
INSTITUTION: University of California Berkeley
DATE: April 25, 2013

NAME: Martyn T. Smith
POSITION: Professor and Director, Berkeley Institute of the Environment
INSTITUTION: School of Public Health, University of California at Berkeley
DATE: May 19, 2013

NAME: Dr. Allison A. Snow
POSITION: Professor of Biology
INSTITUTION: Ohio State University
DATE: April 25, 2013

NAME: Janne Soininen
POSITION: Assistant Professor
INSTITUTION: Department of Geosciences and Geography, University of Helsinki
DATE: 14.5.2013

NAME: Manuel Soler
POSITION: Full Professor
INSTITUTION: Department of Zoology, Granada University, Spain
DATE: 25 April 2013

NAME: Michael Soule
POSITION: Emeritus Professor,
INSTITUTION: UCSC
DATE: 4-25-13

NAME: Wayne P. Sousa
POSITION: Professor
INSTITUTION: Department of Integrative Biology, University of California, Berkeley
DATE: April 29, 2013

NAME: Donald W. Spady MD, MSc.
POSITION: Adjunct Associate Professor of Pediatrics & Public Health
INSTITUTION: Faculty of Medicine & Dentistry, and School of Public Health, University of Alberta, Edmonton, Canada
DATE: April 28, 2013

NAME: Chelsea Specht
POSITION: Associate Professor and Curator
INSTITUTION: University of California, Berkeley
DATE: 29 April 2013

NAME: THOMAS WIER STAFFORD, JR
POSITION: RESEARCH PROFESSOR
INSTITUTION: DEPARTMENT OF PHYSICS & ASTRONOMY, UNIVERSITY OF AARHUS, AARHUS, DENMARK
DATE: MAY 9, 2013

NAME: Dr Martin J. Steinbauer
POSITION: Senior Research Fellow/Entomologist
INSTITUTION: Department of Zoology, La Trobe University, Melbourne, AUSTRALIA
DATE: 20 May 2013

NAME: Nils Chr. Stenseth
POSITION: Professor and Chair, Center for Ecological and Evolutionary Synthesis, and Chief Scientist, Norwegian Institute of Marine Research
INSTITUTION: University of Oslo
DATE: April 23, 2013

NAME: Jonathon Stillman
POSITION: Associate Professor - and - Adjunct Assistant Professor
INSTITUTION: San Francisco State University - and - University of California Berkeley
DATE: April 29, 2013

NAME: Robert L. Street
POSITION: Campbell Professor in the School of Engineering [Em]
INSTITUTION: Stanford University
DATE: 20 May 2013

NAME: Caroline A E Strömberg
POSITION: Assistant Professor & Curator of Paleobotany
INSTITUTION: University of Washington, Seattle
DATE: 05/19/2013

NAME: Simon N. Stuart, PhD
POSITION: Visiting Professor, Department of Biology and Biochemistry, University of Bath
INSTITUTION: Chair, Species Survival Commission, International Union for Conservation of Nature; Senior Biodiversity Advisor, Conservation International; Senior Biodiversity Advisor, World Conservation Monitoring Centre
DATE: 30 April 2013

NAME: Rashid Sumaila
POSITION: Professor of Ocean and Fisheries Economics
INSTITUTION: Fisheries Centre, University of British Columbia, Vancouver, Canada
DATE: April 10, 2013

NAME: William Sutherland
POSITION: Miriam Rothschild Professor of Conservation Biology
INSTITUTION: University of Cambridge
DATE: 18 May 2013

NAME: Dr. David Suzuki, Emeritus
POSITION: Professor, Sustainable Development Research Institute
INSTITUTION: University of British Columbia, Vancouver, BC, Canada
DATE: April 29, 2013

NAME: Andrew Szasz
POSITION: Professor of Environmental Studies
INSTITUTION: University of California, Santa Cruz
DATE: April 26, 2013

NAME: Alina M. Szmant
POSITION: Professor of Marine Biology
INSTITUTION: Center for Marine Science, University of North Carolina Wilmington
DATE: April 25, 2013

T

NAME: Gary M. Tabor
POSITION: Executive Director
INSTITUTION: Center for Large Landscape Conservation
DATE: 25 April, 2013

NAME: Celine Teplitsky
POSITION: Research scientist
INSTITUTION: CNRS & French Natural History Museum
DATE: 29/04/2013

NAME: John Terborgh
POSITION: Research Professor, Nicholas School of the Environment and Earth Sciences
INSTITUTION: Duke University
DATE: April 29, 2013

NAME: Alexey Tesakov
POSITION: Head of Laboratory for Quaternary Stratigraphy
INSTITUTION: Geological Institute, Russian Academy of Sciences, Moscow, Russia
DATE: May 7, 2013

NAME: John N. Thompson
POSITION: Distinguished Professor of Ecology and Evolutionary Biology
INSTITUTION: University of California, Santa Cruz
DATE: 30 April 2013

NAME: Hiroshi Tomimatsu
POSITION: Associate Professor
INSTITUTION: Department of Biology, Yamagata University, Japan
DATE: May 10, 2013

NAME: Susumu Tomiya
POSITION: Lecturer

INSTITUTION: University of California, Berkeley
DATE: May 1, 2013

NAME: Alan Townsend
POSITION: Professor, Dept of Ecology and Evolutionary Biology Fellow, Institute of Arctic and Alpine Research
INSTITUTION: University of Colorado, Boulder
DATE: April 25, 2013

NAME: ANNA TRAVESET
POSITION: RESEARCH PROFESSOR
INSTITUTION: SPANISH RESEARCH COUNCIL
DATE: APRIL 26, 2013

U

V

NAME: James W. Valentine
POSITION: Professor of Integrative Biology, Emeritus
INSTITUTION: UC Berkeley
DATE: April 19, 2013

NAME: Myriam VALERO
POSITION: Researcher at the CNRS (Centre National de la Recherche Scientifique)
INSTITUTION: Station Biologique de Roscoff, France
DATE: 1st May 2013

NAME: Fernando Valladares
POSITION: Research Professor
INSTITUTION: Spanish Council for Scientific Research (CSIC)
DATE: April 24, 2013

NAME: Jan van der Made
POSITION: Scientific researcher (Investigador científico)
INSTITUTION: Consejo Superior de Investigaciónes Científicas (CSIC), Museo Nacional de Ciencias Naturales (Madrid, Spain).
DATE: 25-4-2013

NAME: Marcel van Tuinen
POSITION: Associate Professor
INSTITUTION: UNC at Wilmington
DATE: 4/25/13

NAME: Jake Vander Zanden
POSITION: Professor
INSTITUTION: University of Wisconsin-Madison
DATE: 4/25/2013

NAME: Ella Vázquez-Domínguez, PhD
POSITION: Full time Researcher,
INSTITUTION: Instituto de Ecología, UNAM, México
DATE: 12 May 2013

NAME: Geerat J. Vermeij
POSITION: Distinguished Professor of Geology, Department of Geology
INSTITUTION: University of California at Davis
DATE: April 25, 2013

NAME: Montserrat Vila
POSITION: Reserach Professor
INSTITUTION: estación Biológica de Doñana (EBD-CSIC)
DATE: April, 25th, 2013

NAME: Peter Vitousek
POSITION: Professor
INSTITUTION: Stanford University
DATE: April 26, 2013

NAME: Kristiina Vogt
POSITION: Professor and Director of FSB, School of Environmental and Forest Sciences, College of the Environment
INSTITUTION: University of Washington
DATE: 6 May 2013

NAME: Henrik von Wehrden
POSITION: Junior Professor
INSTITUTION: Leuphana University, Gemany, Institute of Ecology/Faculty of Sustainability & Center for Methods
DATE: 18.05.2013

W

NAME: Mathis Wackernagel, Ph.D.
POSITION: President, Global Footprint Network, and Visiting Professor
INSTITUTION: Cornell University
DATE: 28 April 2013

NAME: David B. Wake
POSITION: Professor of the Graduate School in Integrative Biology
INSTITUTION: University of California at Berkeley
DATE: April 25, 2013

NAME: Marvalee H. Wake
POSITION: Professor of the Graduate School, Department of Integrative Biology
INSTITUTION: University of California-Berkeley
DATE: April 23, 2013

NAME: Diana H. Wall
POSITION: University Distinguished Professor and School of Global Environmental Sustainability
INSTITUTION: Colorado State University
DATE: April 25, 2013

NAME: Don Waller
POSITION: John T. Curtis Professor of Botany and Chair, Department of Botany, Biological Aspects of Conservation Major, Wisconsin Ecology
INSTITUTION: University of Wisconsin – Madison
DATE: April 26, 2013

NAME: Dr Haydn Washington
POSITION: Visiting Fellow, Institute of Environmental Studies
INSTITUTION: University of New South Wales (Australia)
DATE: 29 April 2013

NAME: Les Watling
POSITION: Professor
INSTITUTION: University of Hawaii at Manoa
DATE: 26 April 2013

NAME: David M Watson
POSITION: Associate Professor in Ecology
INSTITUTION: Charles Sturt University
DATE: 26 April 2013

NAME: Andrew Weaver
POSITION: Lansdowne Professor and Canada Research Chair
INSTITUTION: School of Earth and Ocean Sciences, University of Victoria
DATE: April 25, 2013

NAME: Anthony LeRoy Westerling
POSITION: Associate Professor, Geography and Environmental Engineering
INSTITUTION: Sierra Nevada Research Institute, University of California, Merced
DATE: April 26, 2013

NAME: Dr Desley Whisson
POSITION: Lecturer in Wildlife and Conservation Biology
INSTITUTION: School of Life and Environmental Sciences, Deakin University
DATE: 18 May 2013

NAME: Tim D. White
POSITION: Professor, Department of Integrative Biology
INSTITUTION: The University of California at Berkeley
DATE: May 1, 2013

NAME: Ruscena Wiederholt
POSITION: Assistant Research Scientist
INSTITUTION: University of Arizona
DATE: 4/25/13

NAME:RICARDO LOPEZ WILCHIS
POSITION:Senior Researcher and Professor
INSTITUTION: Universidad Autónoma Metropolitana-Iztapalapa, Departamento de Biología
DATE: May 11, 2013

NAME: J. Allen Williams, Jr.
POSITION: Professor Emeritus

INSTITUTION: University of Nebraska-Lincoln
DATE: May 3, 2013

NAME: Susan L. Williams
POSITION: Professor
INSTITUTION: Dept. of Evolution & Ecology and Bodega Marine Laboratory, University of California at Davis
DATE: 25 April 2013

NAME: Gregory P. Wilson
POSITION: Assistant Professor of Biology, Adjunct Curator of Vertebrate Paleontology
INSTITUTION: University of Washington and Burke Museum
DATE: May 13, 2013

NAME: Ragnar Winther
POSITION: Professor of Mathematics
INSTITUTION: University of Oslo, Norway
DATE: 10 May, 2013

NAME: Connie Woodhouse
POSITION: Professor
INSTITUTION: School of Geography and Development, University of Arizona
DATE: May 16, 2013

NAME: Dawn J. Wright, Ph.D., GISP
POSITION: Chief Scientist
INSTITUTION: Environmental Systems Research Institute (Esri)
DATE: April 26, 2013

NAME: Carl Wunsch
POSITION: Cecil and Ida Green Professor of Physical Oceanography, emeritus, MIT and Visiting Professor of Physical Oceanography and Climate
INSTITUTION: Harvard U. and MIT.
DATE: 14 May 2013

X

Y

NAME: Norman Yan, PhD, FRSC
POSITION: Professor
INSTITUTION: York University, Toronto, Canada
DATE: April 28, 2013

NAME: Ruifu Yang
POSITION: Professor
INSTITUTION: Beijing Inst. Microbiol. Epidemiol.
DATE: 19 May, 2013

NAME: Charles Yanofsky
POSITION: Emeritus Professor of Biology
INSTITUTION: Stanford University
DATE: May 17, 2013

NAME: Thamasak Yeemin, D.Sc.
POSITION: D. Sc., Marine Biodiversity Research Group, Department of Biology, Faculty of Science
INSTITUTION: Ramkhamhaeng University, Huamark, Bangkok 10240, THAILAND
DATE: 21 May 2013

Z

NAME: Dr Jan Zalasiewicz
POSITION: Senior Lecturer in Palaeobiology
INSTITUTION: University of Leicester
DATE: 7 May 2013

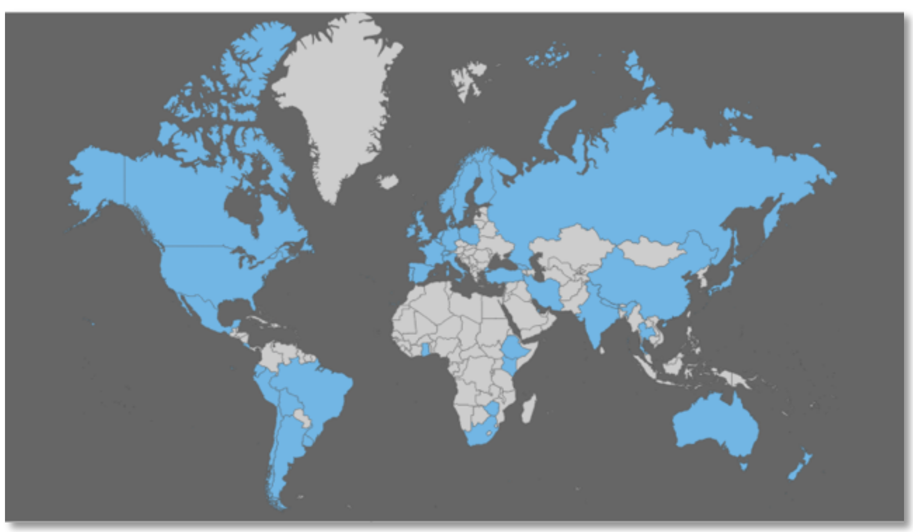
NAME: Luis Zambrano
POSITION: Professor / Reseracher
INSTITUTION: Biology Insitute at National Autonomous Univeristy of Mexico
DATE: May 3rd 2013

NAME: Hugo Tomás Zamora Meza
POSITION: Biologist,
INSTITUTION: Research Associate at the Natural History Museum of the National University of St Augustin of Arequipa, Peru - Bat Conservation Program in Peru
DATE: May 2, 2013

NAME: Kelly R. Zamudio
POSITION: Professor of Ecology & Evolutionary Biology
INSTITUTION: Cornell University
DATE: April 29, 2013

NAME: Joy B. Zedler
POSITION: Professor of Botany and Aldo Leopold Chair of Restoration Ecology
INSTITUTION: University of Wisconsin - Madison
DATE: 4/30/2013

NAME: Liping Zhou
POSITION: Professor, Department of Geography
INSTITUTION: Peking University
DATE: 18 May 2013



Countries (blue) from which 522 scientists have signed as of May 21, 2013.

Purpose of This Consensus Statement

Since about 1950, the world has been changing faster, and to a greater extent, than it has in the past 12,000 years. Balancing the positive changes against the negative ones will be the key challenge of the 21st century.

Positive change has included the Green Revolution, which reduced world hunger (although 1 in 8 people still do not have enough to eat); new medical breakthroughs that have reduced infant and childhood mortality and allow people to live longer and more productive lives; access to myriad goods and services that increase wealth and comfort levels; and new technological breakthroughs, such as computers, cell phones, and the internet, that now connect billions of people throughout the world into a potential global brain.

In contrast, other changes, all interacting with each other, are leading humanity in dangerous directions: **climate disruption, extinction of biodiversity, wholesale loss of vast ecosystems, pollution**, and **ever-increasing numbers of people** competing for the planet's resources. Until now, these have often been viewed as "necessary evils" for progress, or collateral damage that, while unfortunate, would not ultimately stand in the way of serving the needs of people.

Several recent comprehensive reports by the scientific community, however, have now shown otherwise. Rather than simply being inconveniences, the accelerating trends of climate disruption, extinction, ecosystem loss, pollution, and human population growth in fact are threatening the life-support systems upon which we all depend for continuing the high quality of life that many people already enjoy and to which many others aspire.

The vast majority of scientists who study the interactions between people and the rest of the biosphere agree on a key conclusion: that the five interconnected dangerous trends listed above are having detrimental effects, and if continued, the already-apparent negative impacts on human quality of life will become much worse within a few decades. The multitude of sound scientific evidence to substantiate this has been summarized in many recent position papers and consensus statements (a few samples are listed on pp. 28-29), and documented in thousands of articles in the peer-reviewed scientific literature. However, the position papers and consensus statements typically focus only on a subset of the five key issues (for example, climate change, or biodiversity loss, or pollution), and access to the peer-reviewed literature is often difficult for non-scientists. As a result, policy makers faced with making critical decisions can find it cumbersome both to locate the pertinent information and to digest the thousands of pages through which it is distributed.

Here we provide a summary intended to:

- Be useful to policy makers and others who need to understand the most serious environmental-health issues that affect both local constituencies and the entire planet.
- Clearly voice the consensus of most scientists who study these issues that:
  - **Climate disruption, extinction, ecosystem loss, pollution,** and **population growth** are serious threats to humanity's well-being and societal stability; and
  - These five major threats do not operate independently of each other.

We also outline broad-brush actions that, from a scientific perspective, will be required to mitigate the threats. The intent is to provide information that will be necessary and useful if the desire of the general public, governments, and businesses is to maximize the chance that the world of our children and grandchildren will be at least as good as the one in which we live now.

Background Information: Dangerous Trends in our Life Support Systems

People have basic needs for food, water, health, and a place to live, and additionally have to produce energy and other products from natural resources to maintain standards of living that each culture considers adequate. Fulfilling all of these needs for all people is not possible in the absence of a healthy, well-functioning global ecosystem. The "global ecosystem" is basically the complex ways that all life forms on Earth—including us—interact with each other and with their physical environment (water, soil, air, and so on). The total of all those myriad interactions compose the planet's, and our, life support systems.

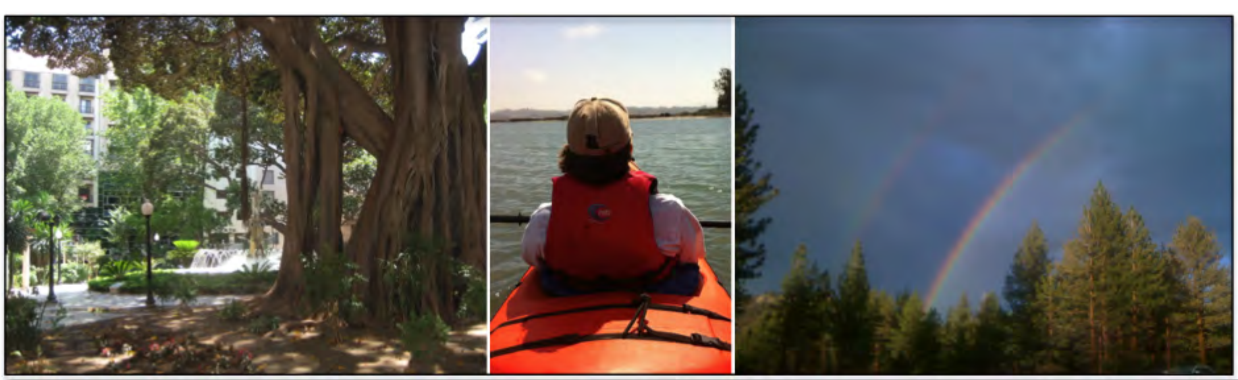
Humans have been an integral part of the global ecosystem since we first evolved; now we have become the dominant species in it. As such, we strongly influence how Earth's life support systems work, in both positive and negative ways. A key challenge in the coming decades is to ensure that the negative influences do not outweigh the positive ones, which would make the world a worse place to live. Robust scientific evidence confirms that five interconnected negative trends of major concern have emerged over the past several decades:

- **Disrupting the climate** that we and other species depend upon.
- **Triggering a mass extinction** of biodiversity.
- **Destroying diverse ecosystems** in ways that damage our basic life support systems.
- **Polluting our land, water, and air** with harmful contaminants that undermine basic biological processes, impose severe health costs, and undermine our ability to deal with other problems.
- **Increasing human population rapidly** while relying on old patterns of production and consumption.

These five trends interact with and exacerbate each other, such that the total impact becomes worse than the simple sum of their parts.

Ensuring a future for our children and grandchildren that is at least as desirable as the life we live now will require accepting that we have already inadvertently pushed the global ecosystem in dangerous directions, and that we have the knowledge and power to steer it back on course—if we act now. Waiting longer will only make it harder, if not impossible, to be successful, and will inflict substantial, escalating costs in both monetary terms and human suffering.

The following pages summarize the causes of each of the five dangerous trends, why their continuation will harm humanity, how they interact to magnify undesirable impacts, and broad-brush solutions necessary to move the human race toward a sustainable, enjoyable future.



Rising to the Challenge

Defusing the five global crises summarized on the following pages will not be easy, but past experience demonstrates that problems of this huge scale are indeed solvable—if humanity is ready to rise to the challenge. Solutions will require the same things that worked successfully in dealing with past global crises: individual initiative, cooperation both within and across national boundaries, technological advances, and emplacing new infrastructure. Individual initiative has seldom been in short supply and continues to be a powerful human resource. Successful global-through-local cooperation resulted in ending World War II and rebuilding afterwards; banning use of nuclear weapons; dramatically increasing global food production with the Green Revolution and averting food crises through United Nations initiatives; greatly reducing the use of persistent toxic chemicals like DDT; reversing stratospheric ozone depletion (the "ozone hole"); and diminishing infectious diseases such as malaria and polio worldwide.

Likewise, past technological advances and the building of new infrastructure have been remarkable and commensurate in scale with what is needed to fix today's problems. For instance, in just seven years, responding to demands of World War II, the United States built its airplane fleet from about 3100 to 300,000 planes, and beginning in the 1950s, took less than 50 years to build 47,000 miles (75,639 km) of interstate highways—enough paved roads to encircle Earth almost twice. Over about the same time, 60% of the world's largest rivers were re-plumbed with dams. In about 30 years, the world went from typewriters and postage stamps to hand-held computers and the internet, now linking a third of the world's population. During the same time we leapfrogged from about 310 million dial-up, landline phones to 6 *billion* mobile phones networked by satellites and presently connecting an estimated 3.2 billion people.

In the context of such past successes, the current problems of climate disruption, extinction, ecosystem loss, pollution, and growing human population and consumption are not too big to solve in the coming 30 to 50 years. Indeed, the scientific, technological, and entrepreneurial pieces are in place, and encouraging initiatives and agreements have begun to emerge at international, national, state, and local levels. Moreover, today's global connectivity is unprecedented in the history of the world, offering the new opportunity for most of the human population to learn of global problems and to help coordinate solutions.

Three key lessons emerge from the examples given above. The first is that global-scale problems must be acknowledged before they can be solved. The second is that fixing them is eminently possible through 'win-win' interactions between local communities, where solutions are actually developed and always emplaced, and higher levels of government, which define priorities backed by clear incentives. The third very important lesson is that big problems cannot be fixed overnight. Given inherent lag times in changing climate, building infrastructure, changing societal norms, and slowing population growth, actions taken today will only begin to bear full fruit in a few decades. If, for example, we move most of the way towards a carbon-neutral energy system by 2035, climate still will not stabilize before 2100, and it will still be a different climate than we are used to now. But, if we delay action to 2035, not only will climate disruption continue to worsen, but efforts at mitigation and adaptation will cost dramatically more; climate would not stabilize until well after the year 2100, and when it did, it would be at an average climate state that is far more disruptive to society than would have been the case if we had acted earlier. Similar costs of delay accrue for the other problems as well; indeed, delaying action on those problems will lead to irretrievable losses of species, ecosystems, and human health and prosperity. Starting *today* to diffuse the global crises we now face is therefore crucial.

Climate Disruption

It is now clear that people are changing Earth's climate by adding greenhouse gases to the atmosphere primarily through the burning of coal, oil (and its by-products like gasoline, diesel, etc.), and natural gas[1]. The overall trend, still continuing, has been to raise the average temperature of the planet over the course of the last century, and especially the last 60 years. Raising average global temperature causes local changes in temperature, in amount and timing of rainfall and snowfall, in length and character of seasons, and in the frequency of extreme storms, floods, droughts, and wildfires[1,2]. Sea-level rise is a particular concern in coastal areas[1-4]. Such impacts directly influence the wellbeing of people through damaging their livelihoods, property, and health, and indirectly through increasing potentials for societal conflict. Recent examples include the flooding from superstorm Sandy on the east coast of the United States, record wildfires and drought throughout the western United States and Australia, heat waves and drought in Europe, and floods in Pakistan, all of which occurred in 2012 and 2013.

The main greenhouse gases emitted by human activities are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). Of these, CO_2 is particularly important because of its abundance. Human-produced ozone-forming chemicals also are contributing to climate change.

Causes for Concern

Even best-case emissions scenarios (the IPCC B1 scenario)[1] project that Earth will be hotter than the human species has ever seen by the year 2070, possibly sooner[1,5]. Continuing current emission trends[6] would, by the time today's children grow up and have grandchildren (the year 2100), likely[a] cause average global temperature to rise between 4.3-11.5°F (2.4-6.4°C), with the best estimate being 7.2°F (4°C)[1]. The last time average global temperature was 7.2°F hotter was some 14 million years ago. The last time it was 11.5°F hotter was about 38 million years ago[7].

Impacts that would be detrimental to humanity by 2100, if not before, should greenhouse gas emissions continue at their present pace, include the following [2,8-10].

- **Longer and more intense heat waves.** The 1-in-20 year hottest day is likely[a] to become a 1-in-2 year event[b] by the end of the 21st century in most regions[2]. Such effects already are being observed—in 2013, temperatures in Australia rose so much that weather maps had to add two new colors to express the new hot extremes. Some models indicate that the current trajectory of warming, if continued to the year 2100, would cause some areas where people now live to be too hot for humans to survive[11].

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[a] The term "likely" in this context implies that there is a 66-100% chance of the effect occurring. Usage here follows definitions explained in IPCC publications. See reference 1 and 2.

[b] For the IPCC A1B and A2 emissions scenarios, see reference 2.

- **More frequent damaging storms.** The 1-in-20 year annual maximum daily precipitation amount is likely[a] to become a 1-in-5 to1-in-15 year event by the end of the 21st century in many regions[c]. Cyclone wind speeds are likely[a] to increase. Cities would experience the extent of damage caused by superstorm Sandy on a more frequent basis.

- **Major damage to coastal cities as sea level rises.** The extent of sea-level rise will depend in part on how fast glaciers melt. Low-end projections[1] call for a rise in sea level of 0.6-1.9 feet (0.18 to 0.59 m) by 2100; high-end projections suggest seas rising as high as 2.6-13.1 feet (0.8-4.0 meters)[3,4,9]. Raising sea level to even the lower estimates would flood large parts of major cities worldwide and force the permanent resettlement of millions of people; about 100 million people now live less than 3.3 feet (1 meter) above mean sea level[12].

- **Water shortages in populous parts of the world.** Cities and farmlands that rely on the seasonal accumulation of snow pack and slow spring melt, arid regions that apportion water from major rivers, and regions that depend on water from glacier melt all are at risk[12].

- **Local reduction of crop yields**. New climate patterns will change which crops can be grown in which areas. Some regions are projected to experience overall declines: for instance, cereal crop production is expected to fall in areas that now have the highest population density and/or the most undernourished people, notably most of Africa and India[12]. Key crop-growing areas, such as California, which provides half of the fruits, nuts, and vegetables for the United States, will experience uneven effects across crops, requiring farmers to adapt rapidly to changing what they plant[13,14].

- **Economic losses, social strife and political unrest.** Damage to coastal areas, flooding of ports, water shortages, adverse weather and shifts in crop-growing areas, creation of new shipping lanes, and competition for newly accessible arctic resources all will complicate national and international relations, and cost billions of dollars[9,10,14,15]. For instance, the New York Times reported[d] that by the first months of 2013, United States taxpayers had already paid $7 billion to subsidize farmers for crops that failed because of extreme drought, and that figure is anticipated to rise as high as $16 billion.

- **Spread of infectious disease.** As temperate regions warm, costly and debilitating mosquito-borne diseases such as malaria are expected to increase in both developed and developing nations[16]. Indeed, expansion of West Nile virus into the United States beginning in 1999 has already occurred, and bluetongue virus, a costly livestock disease carried by midges, has expanded northward into central and northern Europe in the past decade. Besides human suffering, the human-health costs caused by climate change are anticipated to be $2-4 billion per year by 2030[16].

- **Pest expansions that cause severe ecological and economic losses.** For example, over the past two decades, millions of acres of western North American forests have been killed by pine beetles whose populations have exploded as a result of warmer winter temperatures—previously, extreme winter cold prevented abundant beetle survival[17]. The beetle kill reduces wood production and sales, and lowers property values in developed areas.

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[c] For the IPCC B1, A1B, and A2 emissions scenarios, see reference 2.

[d] Ron Nixon, January 15, 2013, Record taxpayer cost is seen for crop insurance, New York Times.

- **Major damage to unique ecosystems.** Warming and acidification of ocean water is expected to destroy a large portion of the world's coral reefs, essentially the "rainforests of the sea" so-called because they host most of the oceans' biodiversity[9,18]. On land, forests worldwide face drought-induced decline, both in dry and wet regions[19]. This is especially problematic in many tropical and subtropical forests[20], which are the cradles of most terrestrial biodiversity.

- **Extinction of species.** Currently at least 20-40% of assessed species—amounting to a minimum of 12,000-24,000 species—are possibly at increased risk of extinction if mean global temperature increases 2.7-4.5^{o}F (1.5-2.5^{o}C)[1,12]. Current emissions trends are on track for a 7.2^{o}F (4^{o}C) rise in global mean temperature by 2100, which would put many more species at risk[9]. The situation with population extinctions is much worse, with much higher extinction rates in the basic unit of biodiversity that supplies ecosystem services[21].

Solutions

Avoiding the worst impacts of human-caused climate change will require reducing emissions of greenhouse gases substantially[6,9] and quickly[22]. For instance, in order to stabilize atmospheric concentrations of CO_2 at 450 parts per million by the year 2050, which would give a 50% chance of holding global temperature rise to 2^{o}C, emissions would have to be decreased 5.1% per year for the next 38 years. This rate of reduction has not been achieved in any year in the past six decades, which puts the magnitude and urgency of the task in perspective[6].

"The world needs another industrial revolution in which our sources of energy are affordable, accessible and sustainable. Energy efficiency and conservation, as well as decarbonizing our energy sources, are essential to this revolution."

S. Chu and A. Majumdar, 2012, ref. 24

However, reducing emissions to requisite values over the next 50 years appears possible through coordinated innovation and deployment of new transportation and energy systems, which can be accomplished largely with existing technology[23-26]. This will require rapid scaling-up of carbon-neutral energy production (solar, wind, hydro, geothermal, hydrogen fuel-cells, nuclear, microbe-based biofuels) to replace energy production from fossil fuels. In the transitional decades when fossil fuels will continue to be in widespread use, increased efficiency in energy use (better gas mileage for cars and trucks, more energy-efficient buildings, etc.) will be necessary, as will phasing out coal-fired power plants in favor of lower-emissions facilities (natural gas). While fossil fuels remain in use during the transitional period, carbon capture and storage (CCS) from major emitters like cement and steel plants will probably be necessary. Scaling up carbon-neutral energy production fast enough will likely require legislation and government policies designed to stimulate the right kinds of innovations and realign the economic landscape for energy production[24,27].

Some effects of climate change already are underway (sea level rise, higher frequency of extreme weather, etc.). Plans to adapt to unavoidable climate changes will need to be developed and implemented for cities and public lands. Keeping agricultural areas productive will require changing the crops grown in some places, and ensuring seed stocks that are adapted to new climates. Ultimate monetary costs for climate mitigation and adaptation grow substantially each year action is postponed[13,22].

Extinctions

Biological extinctions cannot be reversed and therefore are a particularly destructive kind of global change. Even the most conservative analyses indicate that human-caused extinction of other species is now proceeding at rates that are 3-80 times faster than the extinction rate that prevailed before people were abundant on Earth[28], and other estimates are much higher[29-32]. If the current rate of extinction is not slowed for species and their constituent populations, then within as little as three centuries the world would see the loss of 75% of vertebrate species (mammals, birds, reptiles, amphibians, and fish), as well as loss of many species of other kinds of animals and plants[28]. Earth has not seen that magnitude of extinction since an asteroid hit the planet 65 million years ago, killing the dinosaurs and many other species. Only five times in the 540 million years since complex life forms dominated Earth have mass extinctions occurred at the scale of what current extinction rates would produce; those mass extinctions killed an estimated 75%-96% of the species known to be living at the time.

Currently, sound scientific criteria document that at least 23,000 species are threatened with extinction, including 22% of mammal species, 14% of birds, 29% of evaluated reptiles, as many as 43% of amphibians, 29% of evaluated fish, 26% of evaluated invertebrate animals, and 23% of plants[33-35]. Populations—groups of interacting individuals that are the building blocks of species—are dying off at an even faster rate than species. The extinction of local populations, in fact, represents the strongest pulse of contemporary biological extinction. For example, since 1970 some 30% of all vertebrate populations have died out[36], and most species have experienced loss of connectivity between populations because of human-caused habitat fragmentation. Healthy species are composed of many, interconnected populations; rapid population loss, and loss of connectivity between populations, are thus early warning signs of eventual species extinction.

Causes for Concern

The world's plants, animals, fungi, and microbes are the working parts of Earth's life-support systems. Losing them imposes direct economic losses, lessens the effectiveness of nature to serve our needs ("ecosystem services," see next page), and carries significant emotional and moral costs.

- **Economic losses.** At least 40% of the world's economy and 80% of the needs of the poor are derived from biological resources[12]. In the United States, for example, commercial fisheries, some of which rely on species in which the majority of populations have already gone extinct, provide approximately one million jobs and $32 billion in income annually[37]. Internationally, ecotourism, driven largely by the opportunity to view currently threatened species like elephants, lions, and cheetahs, supplies 14% of Kenya's GDP (in 2013)[38] and 13% of Tanzania's (in 2001)[39], and in the Galapagos Islands, ecotourism contributed 68% of the 78% growth in GDP that took place from 1999-2005[40]. Local economies in the United States also rely on revenues generated by ecotourism linked to wildlife resources: for example, in the year 2010 visitors to Yellowstone National Park, which attracts a substantial number of tourists lured by the prospect of seeing wolves and grizzly bears, generated $334 million and created more than 4,800 jobs for the surrounding communities[41]. In 2009, visitors to Yosemite National Park created 4,597 jobs in the area, and generated $408 million in sales revenues, $130 million in labor income, and $226 million in value added[42].

- **Loss of basic services in many communities.** Around the world, indigenous and rural communities depend on the populations of more than 25,000 species for food, medicine, and shelter[43].

- **Loss of ecosystem services.** Extinctions irreversibly decrease biodiversity, which in turn directly costs society through loss of ecosystem services[44-46]. "Ecosystem services" (see the box) are attributes of ecological systems that serve people. Among the ecosystem services that support human life and endeavors are: moderating weather; regulating the water cycle, stabilizing water supplies; filtering drinking water; protecting agricultural soils and replenishing their nutrients; disposing of wastes; pollinating crops and wild plants; providing food from wild species (especially seafood); stabilizing fisheries; providing medicines and pharmaceuticals; controlling spread of pathogens; and helping to reduce greenhouse gases in the atmosphere [34,45]. In contrast to such directly quantifiable benefits promoted by high biodiversity, reducing biodiversity generally reduces the productivity of ecosystems, reduces their stability, and makes them prone to rapidly changing in ways that are clearly detrimental to humanity[45]. For example, among other costs, the loss of tropical biodiversity from deforestation often changes local or regional climate, leading to more frequent floods and droughts and declining productivity of local agricultural systems. Tropical deforestation can also cause new diseases to emerge in humans, because people more often encounter and disrupt animal vectors of disease[47,48].

> *The world's ecosystems are* Natural Capital *that provides vital benefits called* Ecosystem Services *necessary for:*
>
> Production of goods *(crops, timber, seafood)*
>
> Life-support systems *(provision and purification of water, buffering against storms, floods, and droughts)*
>
> Life-fulfilling amenities *(beauty, opportunity for recreation, and the associated physical and mental health benefits)*
>
> Options *(genetic diversity for future use in agriculture, energy, pharmaceuticals and other industries)*
>
> *Modified from G. Daily et al., 2000, ref. 46*

- **Intangible values.** Continuing extinction at the present pace would considerably degrade quality of life for hundreds of millions of people who find emotional and aesthetic value in the presence of iconic species in natural habitats. In this context species are priceless, in the sense of being infinitely valuable. An apt metaphor is a Rembrandt or other unique work of art that evokes exceptional human feelings, and whose loss would be generally recognized as making humanity poorer.

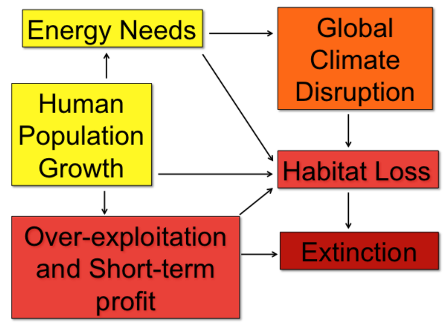
Chief Drivers of Extinction

The main drivers of human-caused extinction[28,30-32,35,49] are:

- **Habitat destruction from ecosystem transformation.** Such practices as unsustainable forestry and conversion of land to agriculture, suburban sprawl, and roads, all cause both habitat destruction and habitat fragmentation. In particular, logging and clearing of tropical rainforests for ranching or farming permanently destroys the habitats for vast numbers of species. Such areas are among the most important reservoirs of terrestrial biodiversity, harboring thousands of unique species and plant and animal functional groups (ecological niches) found nowhere else[43]. In the oceans, habitat destruction and fragmentation results from pollution, trawling, shipping traffic, and shipping noise (sonar, etc.).

- **Environmental Contamination.** Environmental contamination from human-made chemicals contributes to extinction pressures by destroying habitats (for instance, mine dumps, oil spills and agricultural runoff), by direct toxic effects of pollutants, and through subtle effects on animals' immune and reproductive systems.

- **Climate change.** Extinctions result when species cannot move fast enough to find climatic refuges as the climate becomes unsuitable where they now live; when climate changes such that it exceeds their physiological, developmental, or evolutionary tolerances; or when critical species interactions (the way one species depends on the next) are disrupted[50]. On land, models predict that by the year 2100, between 12% and 39% of the planet will have developed climates that no living species has ever experienced, and conversely, the climate that many species currently live in will disappear from 10% to 48% of Earth's surface[51]. These changes will be most pronounced in areas that currently harbor most of the world's biodiversity. In the oceans, acidification, a by-product of climate change that disrupts growth and development of marine organisms, is of particular concern, because it prevents marine shelly animals such as clams and oysters from building their shell, and causes collapse of physical reef infrastructure on which most marine species ultimately depend.



Extinction rates are now too high because old models of natural resource use are no longer sustainable. Supplying 7 billion people (9.5 billion by 2050) with a high quality of life requires investing in nature's capital, rather than spending down its principle.

If current rates of elephant poaching continue, there would be no more wild elephants* on Earth within 20-30 years. The bulk of the short-term profits go to organized crime and terrorist groups. In contrast, revenues from ecotourism are sustainable for the long run and contribute directly to local economies.

- **Intensive exploitation of wild species for profit.** Some iconic species, such as elephants, rhinoceroses, and tigers are being hunted to extinction to sell their tusks, horns, or other body parts to be made into curios or for purported health products. For example, the demand for

* This assumes continuation of the annual rate of about 25,000 elephants killed in 2011, and a world population of between 420,000-650,000 African elephants[52] plus about 50,000 Asian elephants[53].

ivory from elephant tusks, primarily from Asian markets, has driven the price high enough that elephant poaching has now become a lucrative source of income for international crime rings and terrorist organizations. Other species are being over-utilized as marketable food—this is especially a problem for many ocean fisheries, such as those for Bluefin tuna and Atlantic cod. Demand is outstripping supply for such species—there are now seven times as many humans on the planet as there are wild salmon[54]. In the same vein, the dramatic and rapid clearing of rainforests is motivated by immediate economic yield. In all of these cases, the one-time gain in profit (which benefits relatively few people) is a pittance compared to the loss of natural capital, which supplies important benefits locally and globally for the long term. In economic terms, it is analogous to spending down the principle of an investment rather than living off the interest.

Solutions

Because species losses accrue from global pressures, and species and ecosystem distributions transcend political boundaries, solutions to the extinction crisis require coordination between local actions, national laws, and international agreements, as well as strict enforcement of policies[35,55]. Such a multi-jurisdictional approach is essential to prevent illegal trafficking in wildlife products; enhance protection of species in public reserves; and develop effective policies to ensure sustainable fisheries[35]. Management plans for individual species, as well as for public lands and marine protected areas, will need to include adaptation to climate change[5,9,28,35,56]. Assessment of species risks will need to be accelerated[33], particularly for invertebrate species[34] and fish.

> *"Many actions in support of biodiversity have had significant and measurable results in particular areas and amongst targeted species and ecosystems. This suggests that with adequate resources and political will, the tools exist for loss of biodiversity to be reduced at wider scales."*
>
> *Global Biodiversity Outlook 3, ref. 35*

In addition, it will be necessary to address the root causes of climate change and unnecessary ecosystem transformation (see those sections of this consensus statement, pp. 4 and 11). An important part of the solution will be economic valuation of natural capital and ecosystem services, such that global, regional, and local economies account for the benefits of banking natural capital for the long run, rather than irretrievably depleting finite species resources for short-term economic gain[44,57]. Workable examples already exist in China, where 120 million farmers are being paid to farm in ways that not only yield crops and timber but also stabilize steep slopes, control floods, and maintain biodiversity[44]; in Costa Rica[46], where a national payment system for ecosystem services has helped to change deforestation rates from among the highest in the world to among the lowest; and in New York City, where maintaining natural landscapes for water filtration is more economical than building filtration plants[57].

Ecosystem Transformation

As humans have become more abundant, we have transformed large parts of the Earth's surface from their pre-human "natural" state into entirely different landscapes and seascapes[58]. Some of these transformations have been necessary to support basic human needs; others have been inadvertent and unanticipated.

As of 2012, somewhat more than 41% of Earth's ice-free lands (36% of total land surface) have been commandeered for farms, ranches, logging, cities, suburbs, roads, and other human constructs[59-61]. This equates to an average of a little less than 2 acres of transformed land for each person on Earth. Conversion for agriculture accounts for most of the landscape change, with crops covering about 12% and pastureland about 26% of ice-free land (the percentages are about 10% and 22%, respectively, for the proportion of all Earth's land). Urban lands account for another 3%. On top of that are vast road networks that fragment habitats across some 50% of the entire land surface, dams that modify water flow in more than 60% of the world's large rivers and in many smaller ones[62], and continuing deforestation that has been proceeding at the rate of about 30,000 square kilometers (=11,000 square miles) per year for the past 16 years[63]. This per-year loss is roughly the equivalent of clear-cutting the entire country of Belgium or in the United States, the states of Massachusetts or Hawaii in one year.

Almost half of Earth's ice-free land has already been changed completely by human activities. Nowhere on the land or in the sea is completely free of human influence.

Measuring the percentage of the oceans that have been transformed is much more challenging, but it is clear that pollution, trawling, and ship traffic and noise have caused major changes along most of the world's coastlines[64,65]. For example, bottom trawling alone has been estimated to annually destroy an area of seabed equivalent to twice the area of the continental United States[66]. Human debris, particularly plastics, also is ubiquitous in ocean waters, even far offshore[67].

The human footprint extends even outside of the ecosystems that have been transformed wholesale by people. Nearly every terrestrial ecosystem in the world now integrates at least a few species that ultimately were introduced by human activities[68-70], sometimes with devastating losses in ecosystem services[71], and invasive species now number in the hundreds in most major marine ports[72,73] and in the thousands on most continents[70,74,75]. All told, 83% of the entire land surface exhibits human impact defined as influenced by at least one of the following factors: human population density greater than 1 person per square kilometer (=1 person per 0.4 square miles, or 247 acres); agricultural activity; built-up areas or settlements; being within 15 kilometers (9.3 miles) of a road or coastline; or nighttime light bright enough to be detected by satellites[76,77]. Adding in the effect of climate change, every place on Earth exhibits at least some human impact, even the most remote parts of the land and oceans[78].

Causes for Concern

There are two conflicting concerns with respect to ecosystem transformation.

- **The need to minimize the human footprint to prevent extinction of other species and degradation of essential ecosystem services.** Ecological "tipping points," where whole ecosystems change suddenly and unexpectedly to become less biodiverse and in many cases less productive[79], are known to be triggered by transforming threshold percentages of their areas. Many studies document that when 50% to 90% of patches within a landscape are disturbed, the remaining undisturbed patches undergo rapid, irreversible changes as well[5,80-83]. Therefore, wholesale ecological transformation of more than half of Earth's ecosystems by direct human impacts is prone to trigger unanticipated, irreversible degradation even in ecosystems that are not directly utilized by humans. Such changes already are becoming evident in nitrogen deposition in remote arctic lakes[84], by dwindling populations of once-common species in some nature reserves[85], by millions of acres of beetle-killed forests[17], and by invasive species such as zebra mussels[70,71].

- **The need to feed, house, and provide acceptably high standards of living** for the seven billion people that are now on the planet plus 2.5 billion more that probably will be added over the next three decades[86,87] means that the demands for land use will accelerate (see p. 15, the Population Growth section, for more details on this). Nearly 70% of the arable land that has not yet been converted to agricultural use is in tropical grasslands and forests, which include some of the world's most important biodiversity reservoirs and so far are among the lands least impacted by humans[66]. Farming less arable lands would take even more acres per person than at present, because of lower productivity per acre[88].

> *"Cities, regions, or countries that are not able to provide a high quality of life on a low [Ecological] Footprint will be at a disadvantage in a resource-constrained future."*
>
> *B. Ewing et al., 2010, ref. 77*

Solutions

Because food production is the chief transformer of natural ecosystems, a key challenge will be feeding more people without significantly adding to the existing agricultural and fisheries footprint. Valuing natural capital (as explained earlier in the Extinctions section, p. 7) is a promising approach that can lead to significant gains in both biodiversity and crop yields; for instance, as has been shown by integrating coffee farms with natural landscapes in Costa Rica[89]. Slowing and ultimately stopping the encroachment of agriculture into currently uncultivated areas (especially the few remaining tropical rainforests and savannahs) will probably require regulatory policies and incentives for conservation. Recent studies indicate that even without increasing the agricultural footprint, it is feasible to increase food production adequately in an environmentally sound way through[60,90]: (a) improving yields in the world's currently less productive farmlands; (b) more efficiently using the water, energy, and fertilizer necessary to increase yields; (c) eating less meat; and (d) reducing food waste through better infrastructure, distribution, and more efficient consumption patterns—some 30% of the food currently produced is discarded or spoiled. Adapting crop strains to changing climate will also be required to maximize yields[91,92]. In the oceans, solutions lie in enhanced fisheries management; sustainable aquaculture that focuses on species for which farming does not consume more protein than is produced; and reduction of pollution, especially along coasts[93,94].

It will be necessary to avoid losing more land to suburban sprawl through emphasizing development plans that provide higher-density housing and more efficient infrastructure in existing built-up areas, rather than carving new communities wholesale out of less disturbed surrounding lands.

Climate change will affect all places on the planet—those that are currently little impacted by humanity, as well as those now intensively used for agriculture or cities and towns—and the effects will be more pronounced with greater amounts of warming. Avoiding global ecosystem transformation will therefore also require keeping climate change to a minimum.

Pollution

There are few, if any places on Earth where human-produced environmental contaminants are not being deposited. Traces of pesticides and industrial pollutants are routinely found in samples of soil or tree bark from virtually any forest in the world, in the blubber of whales, in polar bear body tissues, in fish from most rivers and oceans, and in the umbilical cords of newborn babies[66,95]. Smog in many cities is far above levels considered safe[96]. In the worst cases—such as in Beijing during January 2013—polluted air can be seen from space. Other air pollutants, such as greenhouse gases and ozone, are invisible but cause serious global-scale problems, notably climate disruption. Oil spills routinely contaminate oceans and coastlines, as well as inland waters and land areas. Nuclear waste, and especially radioactive contamination from

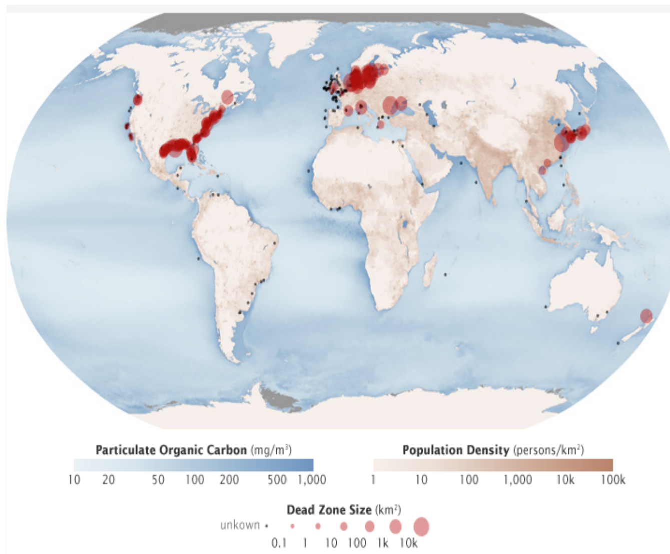
The brown haze of air pollution is pernicious in and around many cities, and causes at up to six million deaths each year. Pictured is the smog accumulating south of San Francisco, California, on a cool winter day.

accidents at nuclear plants, is a growing problem, as is the ubiquity of hormone-disrupting or cancer-causing chemicals such as bisphenol-A (commonly known as BPA)[97]. Activities such as mining, manufacturing, and recycling of electronic equipment have not only concentrated dangerous pollutants locally, but also distributed them worldwide, notably harmful substances such as lead, chromium, mercury, and asbestos[98,99].

Causes for Concern

- **Health impacts.** The health costs of pollution are enormous. At least 125 million people are now at direct risk from toxic wastes produced by mining and manufacturing[98]. As of 2010 air pollution caused up to 6 million premature deaths per year[96,100]. Environmental exposures are thought to contribute to 19% of cancer incidence worldwide[98]. Millions of people drink groundwater contaminated with cancer-causing arsenic or harmful microbes[101]. All total, as of 2010, the number of years lost due to illness, disability or early death (disability-adjusted life years, or DALYS) from environmental hazards is probably greater than those lost to malaria, tuberculosis, and HIV/AIDS combined[100]. An emerging concern is the effect of hormone-simulating chemicals, such as endocrine disruptors, which may be affecting human growth, development, and health on a large scale. For instance, endocrine disruptors have been linked to earlier onset of puberty and obesity[97]. The latter also leads to increased incidence of heart disease and type II diabetes[102].

- **Dead zones.** Excess nitrogen from farm fertilizers, sewage plants, livestock pens, and coal plants eventually ends up waterways and makes it way to the oceans, where it stimulates prodigious algal growth. Decay of the dead algae then sucks all the oxygen out of the water[66,95]. The result is a dead zone where marine life is greatly reduced. Most coasts of the world now exhibit elevated nitrogen flow, with large dead zones occurring near major population centers[103,104].



World distribution of dead zones in the ocean caused primarily by nitrogen pollution. Figure from NASA , ref. 104.

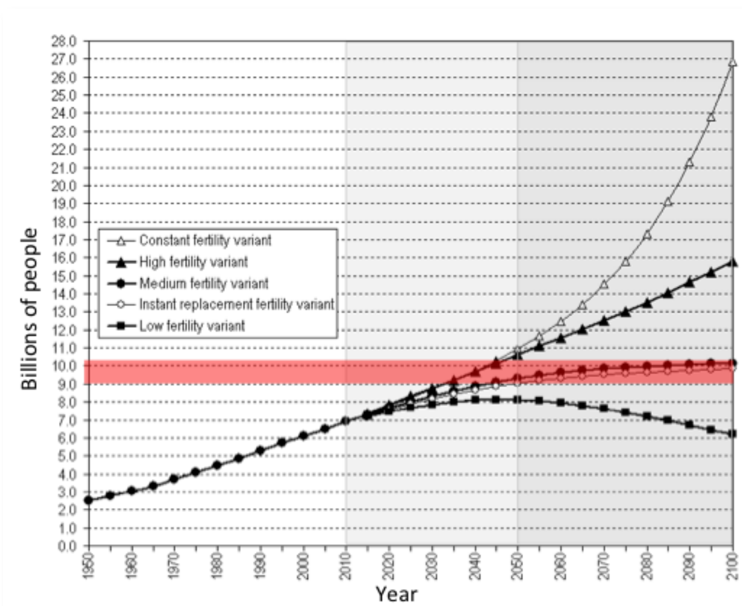
- **Environmental devastation.** Greenhouse gas pollutants—primarily human-produced carbon dioxide (CO_2), nitrous oxide (NO), and methane (CH_4)—are the causes of one of the biggest environmental problems, climate disruption[1]. Herbicides, pesticides, and various chemicals used in plastic production contaminate many waterways directly, and then are taken up by organisms and bioamplified through food chains. Virtually all human beings on Earth carry a burden of these persistent chemicals, many of which are endocrine disruptors. Pharmaceuticals meant for humans or livestock, and subsequently flushed into drains or otherwise finding their way into rivers and lakes, disrupt growth and development of amphibians and fish. Sewage and excess fertilizer contribute significantly to damaging more than half of the world's coral reefs, and in some ecoregions, up to 90% of reefs[66,95].

Solutions

The pollution problem is not a new one. The sources of environmental contamination generally are well known, especially for the worst sources, such as lead-battery recycling, lead smelting, mining and ore processing, tannery operations, municipal and industrial dumpsites, product manufacturing, chemical manufacturing, petrochemical industry, electronic waste, agricultural pesticides and excess fertilizers, and greenhouse gases[66,95,98]. Viable prevention and cleanup solutions are available for most pollutants, but are often not employed because of cost. Significant reductions in pollution from manufacturing can be found in better regulation and oversight of industries using and producing hazardous wastes; better industry practices in controlling hazardous wastes and substances; educating local communities and hazardous industries in adverse effects of pollutants; enhancement of technology for management and treatment of pollutants; and minimizing location of potentially hazardous industries near population centers. Reducing air pollution (including greenhouse gases) requires phasing out coal-fired power plants and high-emissions vehicles immediately, and over time replacing fossil-fuel sources of energy with clean energy. Minimizing agricultural pollution requires maximizing efficiency in application of fertilizers, pesticides, and antibiotics.

Even more promising than these traditional approaches is to use our current scientific understanding of the mechanisms of toxicity to guide synthetic chemistry toward a new generation of inherently safer materials. This is now eminently feasible, and it promises to reward entrepreneurs who adopt these green chemistry approaches in the market[105].

Population Growth and Resource Consumption

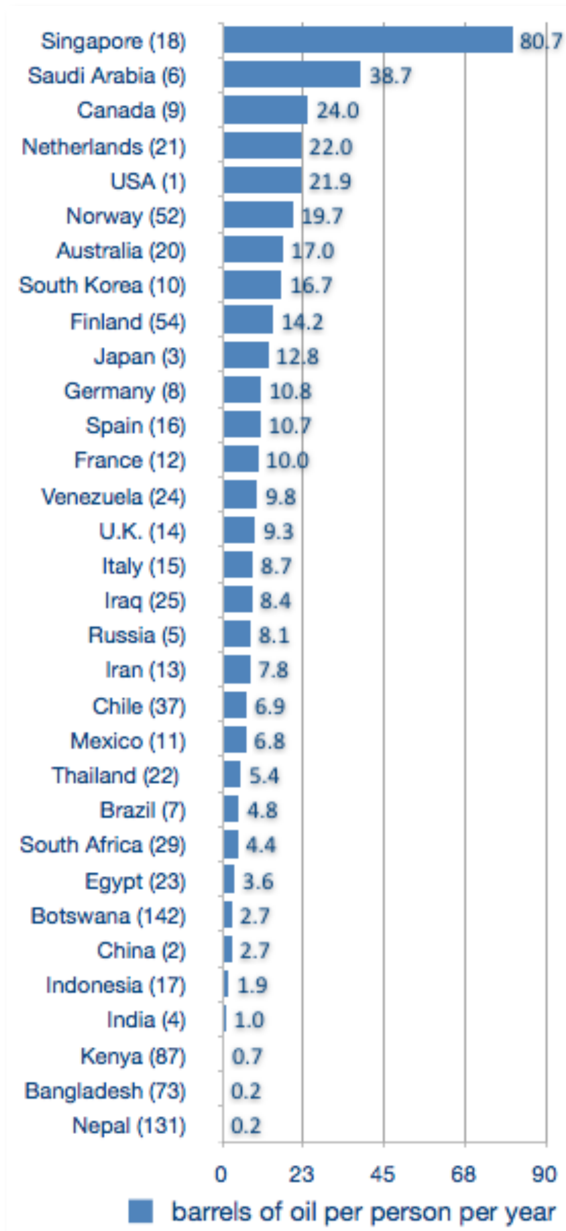


If the fertility rate in all countries rapidly changes so each family on average has one daughter, population will crest by 2050, then stabilize around 10.1 billion. The red line marks a population of 9-10.1 billion. Chart from UNDESA, 2011, ref. 87.

There are two aspects to the population problem. One is how many people are on Earth. The other is the wide disparity in the 'ecological footprint' among different countries and societal sectors, with a relatively small proportion of humanity inefficiently using and impacting an inordinately large proportion of ecological resources.

Today there are more than seven billion people on the planet. Demographic projections of population growth indicate that some 2.5 billion more people may be added to the world population by 2050[86,87], when today's children will be reaching middle age (see the population growth chart at left). How population actually changes in coming decades depends largely on what happens to fertility rates (the average number of children borne per woman in the population in her lifetime), as well as mortality rates. If the global average fertility rate stayed at its present level, there could be 27 billion people on Earth in the year 2100, but that is extremely unlikely. If fertility changed worldwide to "replacement rate" (in which parents just "replaced" themselves in the next generation – about 2.1 children per woman) and mortality rates were those typical of developed countries, then there would be 10.1 billion people in 2100. With a global average fertility rate of ½ child above replacement rate, the population would reach 15.8 billion in 2100, and a rate of ½ child below replacement would lead to an early peak in population size and a decline to about 6.2 billion people by 2100.

There are very wide differences in fertility between countries today. At the low end rates are just 1.2 or 1.3 in several developed countries, including Latvia, Portugal, South Korea, and Singapore. Some countries with slightly higher fertility rates are now declining, including Russia, Germany, and Japan. Virtually all developed countries and a number of developing countries, including China, Brazil, and Thailand, now have below-replacement fertility, and their populations are on track to stop growing within a few decades at most. By contrast, many very poor developing countries still have fertility rates as high as 6 or more children per family: e.g., Zambia, Somalia, Burundi, and Afghanistan, among others. It is the high fertility in these regions that may keep the world population growing for a century more unless population policies lower their fertility sooner rather than later.



Consumption varies dramatically among countries, as illustrated by this graph of average barrels of oil used per person per year in some of the top oil-consuming countries compared to other representative nations. Numbers in parentheses give world rank in oil consumption. Numbers at right are barrels used per person per year (data from CIA Fact Book, 2013, ref. 115). The challenge is bringing down per capita consumption rates in countries in which rates are now too high, while allowing for growth in developing countries that are now at low consumption rates. In the case of fossil fuels, scaling up of renewables and new technological innovations will be required to solve the problem.

Causes for Concern

Each of the seven billion people now on Earth contributes at some level to climate disruption, extinctions, ecosystem transformation, and pollution. The actual contributions of course vary from region to region, country to country, and between rich and poor (see the graph on p. 16), with the general pattern being a much larger per capita footprint in highly industrialized, wealthier countries, and a lower per capita footprint in developing, poorer countries. Although each individual contribution to the global-change footprint can be tiny, when multiplied by billions, the effect becomes inordinately large. Among the key ways population growth contributes to world problems are the following.

- **Climate disruption.** On average each person on Earth produces about 4.9 tonnes of CO_2 per year, as of 2011[106]; thus, as population grows, greenhouse gases and consequent climate dispruption increase proportionately.
- **Extinctions.** Direct causes of extinction (habitat destruction, overexploitation) can be expected to increase as billions more people occupy and use more and more of the planet[66]. Further extinctions are likely to result from climate change. In addition, there are serious indirect impacts, notably the amount of net primary productivity, or NPP[e], that humans consume or co-opt. (NPP is a measure of the "natural energy" available to power the global ecosystem.) Humans now appropriate about 28% of all NPP (although estimates range from 23% to 40%)[58,61,107-109]. There are limits to the amount of NPP that can be produced on Earth, so the more NPP that humans use, the less is available for other species. That means that as the human population grows, populations of other species inevitably go extinct (unless special conservation measures mitigate the losses) because of global energy constraints. Calculations that assume no change in human consumption patterns indicate that the amount of NPP required by 20 billion people—which would occur by the year 2085 if fertility rates stayed the same as they are now—would cause the extinction of most other species on Earth[110]. Clearly, a human population of that size is untenable.
- **Ecosystem Transformation.** A little less than 2 acres of land has already been converted for each person on Earth[5,58,60]. If that per capita rate of land conversion continued, adding 2.5 billion more people to the planet means that the majority of Earth's lands—a little over 50%—would have been changed into farms, pastures, cities, towns, and roads by 2050. Continuing to use land at the rate of 2 acres per person would mean that 85% of Earth's lands would have to be used—including inhospitable places like deserts, the Arctic, and the Antarctic—if the population hit 15 billion. Such unworkable scenarios underscore that population cannot grow substantially without reducing the human footprint.
- **Pollution.** All of the most dangerous sources of pollution result from per capita demand for goods and services and, given current practices, will increase proportionately with the number of people on Earth. Additionally, there is the problem of treating and disposing of human waste (sewage and garbage), which multiplies roughly in proportion to numbers of people.

[e] NPP is defined as the net amount of solar energy converted to plant organic matter through photosynthesis.

An important consideration is that basic needs—a place to live, food, water, and adequate health care—are difficult to provide even for the seven billion people already alive today. Although international programs have been making significant gains in bringing these basic needs to more people and places, about 80% of the world's population still lives below poverty level (i.e., on less than $10 per day; 1.4 billion people still live on less than $1.25 per day)[111]; 2.6 billion people lack basic sanitation services (more than one-third of all the people on the planet)[111]; 1.1 billion people have inadequate access to water[111]; about 870 million people (1 out of every 8) lack enough food[112]; and 1 billion people lack access to basic health care systems[113]. Addition of 2.5 billion more people by 2050, and more after that, would make these already-challenging problems even more difficult to solve, particularly since the highest fertility rates currently are in the poorest countries. For example, despite an overall decrease in malnourished children from 1990 to 2011, the number of underfed children in Africa—where populations have grown substantially and most countries are relatively poor—rose from about 46 million to 56 million in those two decades[114].

Solutions

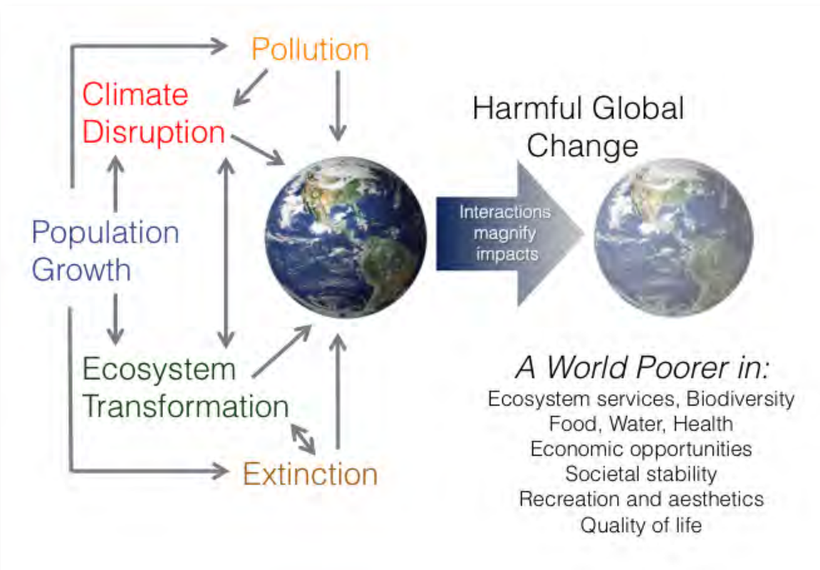
Two strategies will be required to avoid the worst impacts of population growth. The first involves recognizing that sustaining at least the quality of life that exists today while still adding some billions of people will require reducing the per capita human footprint—for example, developing and implementing carbon-neutral energy technologies, producing food and goods more efficiently, consuming less, and wasting less. This amounts to a dual challenge of reducing the per capita use of resources in economically developed countries, while still allowing growth in quality of life in developing countries. For example, the average U.S. citizen used about 22 barrels of oil per year in 2011, whereas the average person in China and India used only about 3 and 1 barrels, respectively (see the graph on p. 16)[115]. Evening out such disparities while still preserving quality of life will require a transformation of energy and resource-consumption regimes in both rich and poor nations, as well as major technological breakthroughs in some areas. Especially in the energy sector, policy changes will be needed to ensure that developing countries can "leap-frog" over outdated technologies, as occurred with the mobile phone industry. Overall, per capita consumption can be reduced by using state-of-the-art science for designing, developing, and commercializing the materials that are used by billions of people.

Access to basic needs like food, water, and health care is difficult or lacking for billions of people, even today.

The second strategy involves ensuring that the lower population-growth projections are the ones that prevail[44,116]. The medium-fertility variant worldwide (on average one daughter per family) would stabilize world population at about 10 billion; that would actually entail a large *increase* in fertility in all developed countries plus China and dozens of other developing countries. Therefore the 10-billion benchmark clearly can be improved upon. Today, about 40% of the population lives in countries where fertility is already near replacement, and another 42% live in countries where the fertility rate is significantly lower. The "low" projection (see the graph on p. 15) is achievable and should be the goal. Ending world population growth at about 8 billion requires bringing down fertility rates in the 18% of the population[87] that live mostly in economically disadvantaged countries, where people still lack ready access to education and health care. Raising levels of education, particularly among women, and providing access to safe and effective means of contraception to those who want it, have been proven to reduce fertility rates substantially[44,117].

Interactions

While climate disruption, extinctions, ecosystem transformation, pollution, and population growth all are serious problems on their own, they interact with each other in ways that make their total effects much more than simply the sum of their parts. For example, pollution leads to local losses of biodiversity, which in turn leads to major ecological changes. Cutting down old-growth rainforests permanently transforms local climate by making it effectively drier, which in turn permanently changes the local ecosystem from forest to grassland. At the same time global climate disruption is magnified as a result of removing a major source of carbon sequestration. Scaling up, as global climate reaches critical thresholds of change, rapid disappearance of whole biomes, such as boreal forests[118], may result. Some pressures are tied intimately to others: for instance, increasing human population size, and especially increasing per capita consumption, multiplies the impacts of all four of the other problems.



The interactions between climate disruption, population growth and consumption, ecosystem transformation, pollution, and extinction greatly magnify the potential for undesirable global change.

Causes for Concern

Interaction effects markedly increase the chances that crossing critical thresholds will lead to irreversible change[79,119]. That means that multiple global pressures can combine to cause undesirable changes to occur more unexpectedly, faster and more intensely than what would be predicted from considering each pressure separately[120-124]. Such unanticipated changes in essential resources—food, water, climate predictability, biodiversity—are likely to result in social strife.

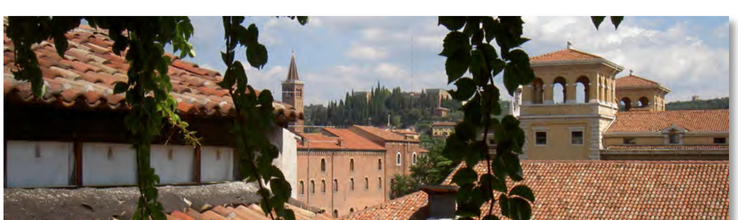
The pressures of each dangerous trend on its own, combined with the multiplying effect of combining them, makes it highly plausible that disruptive societal changes would occur within decades if business as usual continues[5,120,122]. Even taken individually, the current trajectories of climate change, extinctions, ecosystem transformation, pollution, and population growth are faster and greater than the planetary pressures that triggered so-called ‘planetary state-changes’ in the past[5]. Essentially, those were times when the Earth system hit a “tipping point,” that is, suddenly switched to a new condition that precipitated abrupt, major, and permanent changes, including losses of species and shifts in ecological structure and ecosystem services that affected all places on the planet. The last time this happened was nearly 12,000 years ago, when the last glaciation ended. In general, “tipping points” are characteristic of how biological systems respond to continued pressures, and they are well documented at a variety of spatial and temporal scales[79,125].

Solutions

Minimizing the chances that unanticipated global changes will result from interaction effects requires flattening the trajectories of all five dangerous trends[126]. An important part of the solution lies in relieving the global pressures that have the strongest interaction effects, namely population growth, per capita resource consumption, and greenhouse gas emissions. These affect conditions in all parts of the planet, because the extent of ecosystem transformation, extinctions, and pollution inevitably multiply as population grows, as people consume more, and as climate changes, and climate disruption becomes more pronounced as more people use energy derived from fossil fuels.

While the science is clear that continuing the negative trends of climate disruption, extinction, ecosystem loss, pollution, population growth and growing per capita consumption are harmful to humanity, actually solving these problems will require recognition of their urgency by people and governments at all levels. The technological expertise is available to mitigate many of the harmful impacts, but ultimately, science and technology only provide the tools; it is up to society to decide whether or not they want to use them. Therefore, a crucial next step in diffusing these problems is societal recognition of their urgency and willingness to commit human ingenuity and resources towards implementing solutions[88]. This will entail enhanced education about these issues at all levels, including schools, businesses, the media, and governments, and sustainable development goals that acknowledge that human well-being depends on planetary well-being[126].

The window of time for this global effort to begin is short, because the science also demonstrates that with each passing year of business as usual, the problems not only become worse, they become more expensive and difficult to solve, and our chances of avoiding the worst outcomes diminish. Put another way, starting now means we have a good chance of success; delaying even a decade may be too late.



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