

Scientific Consensus on
**Maintaining Humanity's
Life Support Systems in
the 21st Century**

Information for Policy Makers

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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

<p style="text-align: center;">Climate Disruption</p> <p><i>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.</i></p>	
<p style="text-align: center;">Extinctions</p> <p><i>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.).</i></p>	<p style="text-align: center;">Pollution</p> <p><i>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.</i></p>
<p><i>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.</i></p>	
<p style="text-align: center;">Ecosystem Transformation</p> <p><i>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.</i></p>	<p style="text-align: center;">Population Growth and Consumption</p> <p><i>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.</i></p> <p><i>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.</i></p>

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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 Forrester
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

DATE: 20th May, 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: May 16, 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: coordinator 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 2013

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: Raphael Leblois
POSITION: researcher
INSTITUTION: INRA (French National
Institute for Agronomic Research), Lab
"Center for Biology and Population
Management", 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 Sciences, 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
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
University; honorary senior Fellow at
University of Melbourne & Charles
Sturt University)
DATE: 8 May 2013

NAME: Stephen Luby
POSITION: Professor of 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 University
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. Medellín
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 Recherche, 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, 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 Científicas, 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: Giovanni 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 Cientificas
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
Biodiversity 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
Investigaciones 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
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Countries (blue) from which 520 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 gas¹. The overall trend, still continuing, has been to raise the average



The main greenhouse gases emitted by human activities are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (NO). Of these, CO₂ is particularly important because of its abundance. Human-produced ozone-forming chemicals also are contributing to climate change.

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 areas¹⁻⁴. 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.

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 trends⁶ 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 ago⁷.

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 regions². 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 survive¹¹.

^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 to 1-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 projections¹ 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 level¹².
- **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 risk¹².
- **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 India¹². 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 nations¹⁶. 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 2030¹⁶.
- **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 survival¹⁷. The beetle kill reduces wood production and sales, and lowers property values in developed areas.

^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 regions¹⁹. This is especially problematic in many tropical and subtropical forests²⁰, 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°F (1.5-2.5°C)^{1,12}. Current emissions trends are on track for a 7.2°F (4°C) rise in global mean temperature by 2100, which would put many more species at risk⁹. The situation with population extinctions is much worse, with much higher extinction rates in the basic unit of biodiversity that supplies ecosystem services²¹.

Solutions

Avoiding the worst impacts of human-caused climate change will require reducing emissions of greenhouse gases substantially^{6,9} and quickly²². For instance, in order to stabilize atmospheric concentrations of CO₂ at 450 parts per million by the year 2050, which would give a 50% chance of holding global temperature rise to 2°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 perspective⁶.

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 technology²³⁻²⁶. 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}.

“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

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 Earth²⁸, and other estimates are much higher²⁹⁻³². 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 plants²⁸. 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 plants³³⁻³⁵. 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 out³⁶, 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 resources¹². 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 annually³⁷. 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 1999-2005⁴⁰. 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 communities⁴¹. 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 added⁴².

- **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 shelter⁴³.
- **Loss of ecosystem services.** Extinctions irreversibly decrease biodiversity, which in turn directly costs society through loss of ecosystem services⁴⁴⁻⁴⁶. “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 humanity⁴⁵. 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}.
- **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.

*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

Chief Drivers of Extinction

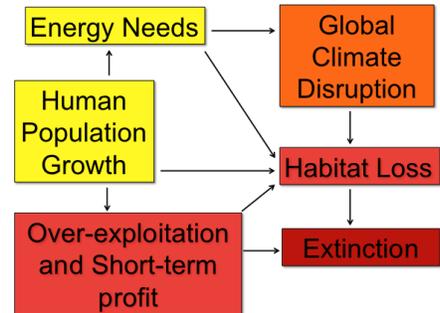
The main drivers of human-caused extinction^{28,30-32,35,49} are:

- **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 else⁴³. 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 disrupted⁵⁰. 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 surface⁵¹. 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 elephants⁵² plus about 50,000 Asian elephants⁵³.

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 salmon⁵⁴. 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 fisheries³⁵. 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 accelerated³³, particularly for invertebrate species³⁴ and fish.

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 biodiversity⁴⁴; in Costa Rica⁴⁶, 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 plants⁵⁷.

“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

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 seascapes⁵⁸. 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 constructs⁵⁹⁻⁶¹. 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,



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.

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 ones⁶², 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 years⁶³. 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.

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 States⁶⁶. Human debris, particularly plastics, also is ubiquitous in ocean waters, even far offshore⁶⁷.

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 activities⁶⁸⁻⁷⁰, sometimes with devastating losses in ecosystem services⁷¹, 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 oceans⁷⁸.

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 productive⁷⁹, 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 lakes⁸⁴, by dwindling populations of once-common species in some nature reserves⁸⁵, by millions of acres of beetle-killed forests¹⁷, 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 humans⁶⁶. Farming less arable lands would take even more acres per person than at present, because of lower productivity per acre⁸⁸.

“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 Rica⁸⁹. 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 safe⁹⁶. 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

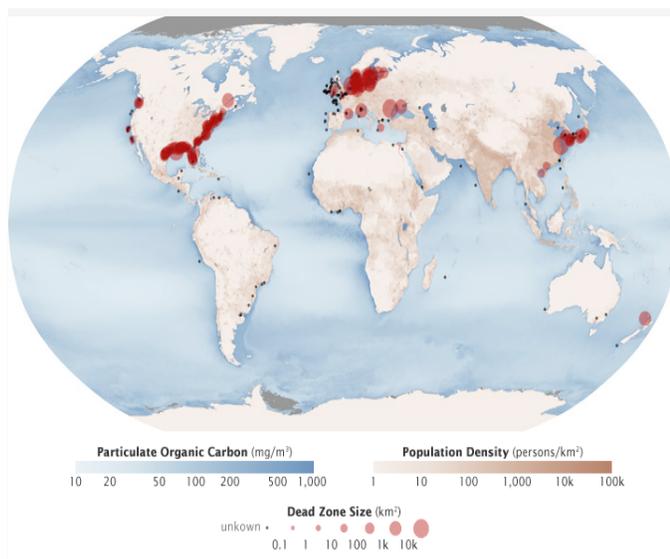


The brown haze of air pollution is pernicious in and around many cities, and causes at up to six million deaths each year. Pictured is the smog accumulating south of San Francisco, California, on a cool winter day.

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 manufacturing⁹⁸. 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 worldwide⁹⁸. Millions of people drink groundwater contaminated with cancer-causing arsenic or harmful microbes¹⁰¹. 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 combined¹⁰⁰. 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 obesity⁹⁷. The latter also leads to increased incidence of heart disease and type II diabetes¹⁰².
- **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}.
- **Environmental devastation.** Greenhouse gas pollutants—primarily human-produced carbon dioxide (CO₂), nitrous oxide (NO), and methane (CH₄)—are the causes of one of the biggest environmental problems, climate disruption¹. 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}.



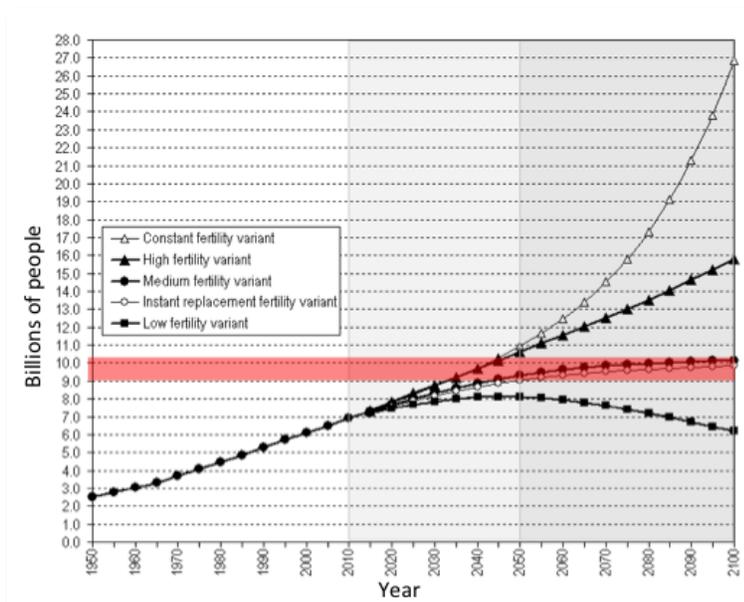
World distribution of dead zones in the ocean caused primarily by nitrogen pollution. Figure from NASA, ref. 104.

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 market¹⁰⁵.

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, 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 CO₂ per year, as of 2011¹⁰⁶; thus, as population grows, greenhouse gases and consequent climate disruption 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 planet⁶⁶. 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 Earth¹¹⁰. 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 water¹¹¹; about 870 million people (1 out of every 8) lack enough food¹¹²; and 1 billion people lack access to basic health care systems¹¹³. 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 decades¹¹⁴.

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.



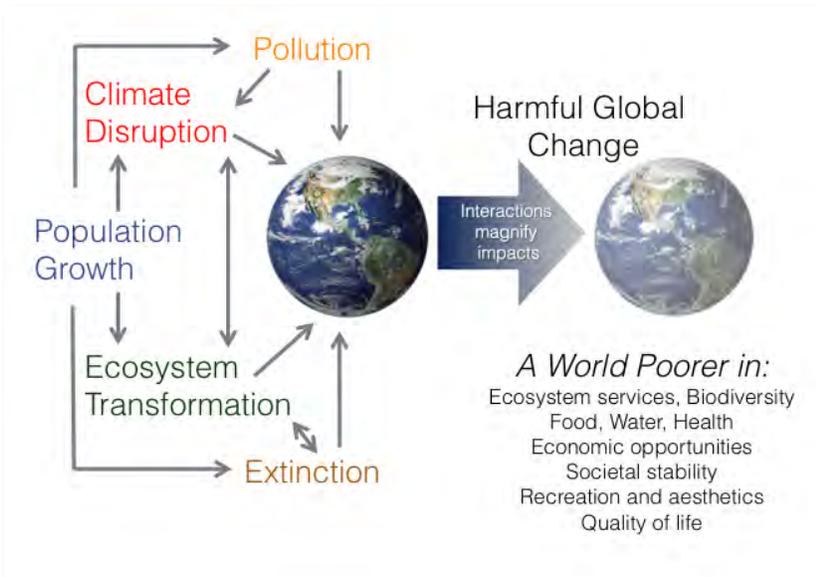
Access to basic needs like food, water, and health care is difficult or lacking for billions of people, even today.

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 population⁸⁷ 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 forests¹¹⁸, 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 separately¹²⁰⁻¹²⁴. 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 past⁵. 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 trends¹²⁶. 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 solutions⁸⁸. 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-being¹²⁶.

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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