Ten Million Places at the Table: Translating Biodiversity Issues

National Academy of Sciences Darwin Symposium

Twenty-first Century Ecosystems:
Systemic Risk and the Public Good
11-12 February 2009

James P. Collins
Assistant Director for Biological Sciences
National Science Foundation

Biology for the 21st Century

A vision for our planet's future based on a comprehensive understanding of the living world across scales of size, time, and place:

"there is a grandeur in this view of life…"

Understanding the Dimensions of Biodiversity

We are the first generation of scientists with the tools to address the dimensions of biodiversity on Earth…

- Current effort: Estimated number of species on Earth divided by the number of species described annually:

  ~ 160 years to complete the task.

Understanding the Dimensions of Biodiversity

And we may be the last generation with the opportunity to discover and understand Earth's extant species before many are lost…

- Thomas et al. (2004, Nature): predict that "on the basis of mid-range climate-warming scenarios for 2050, that 15-37% of species" in their sample of regions and taxa will be "committed to extinction."

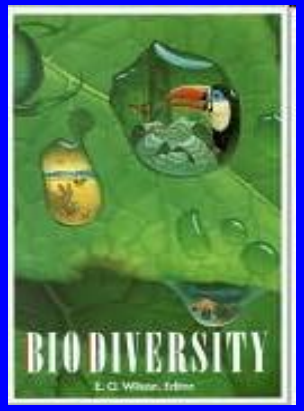
Outline

- History
- Challenges
- “Game changers”
- Case study

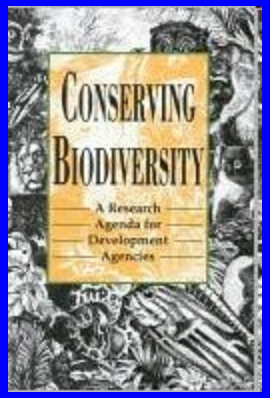
History of Repeated Themes

Research priorities / Socioeconomic benefits / Recommendations

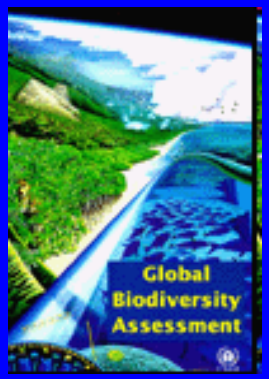
NAS/Smithsonian 1988



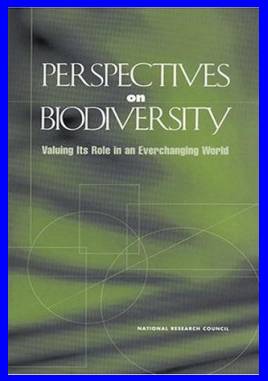
NRC 1992



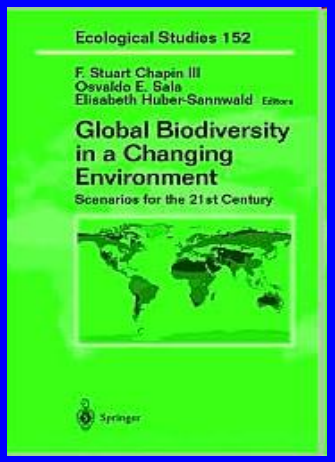
UNEP 1996



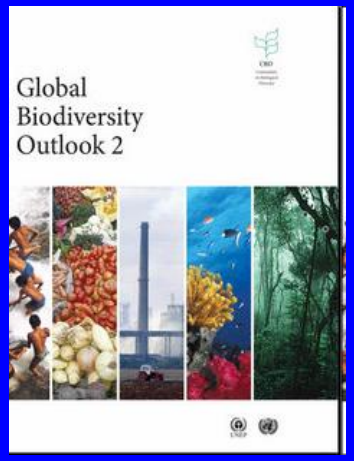
NRC 1999



Monograph 2001



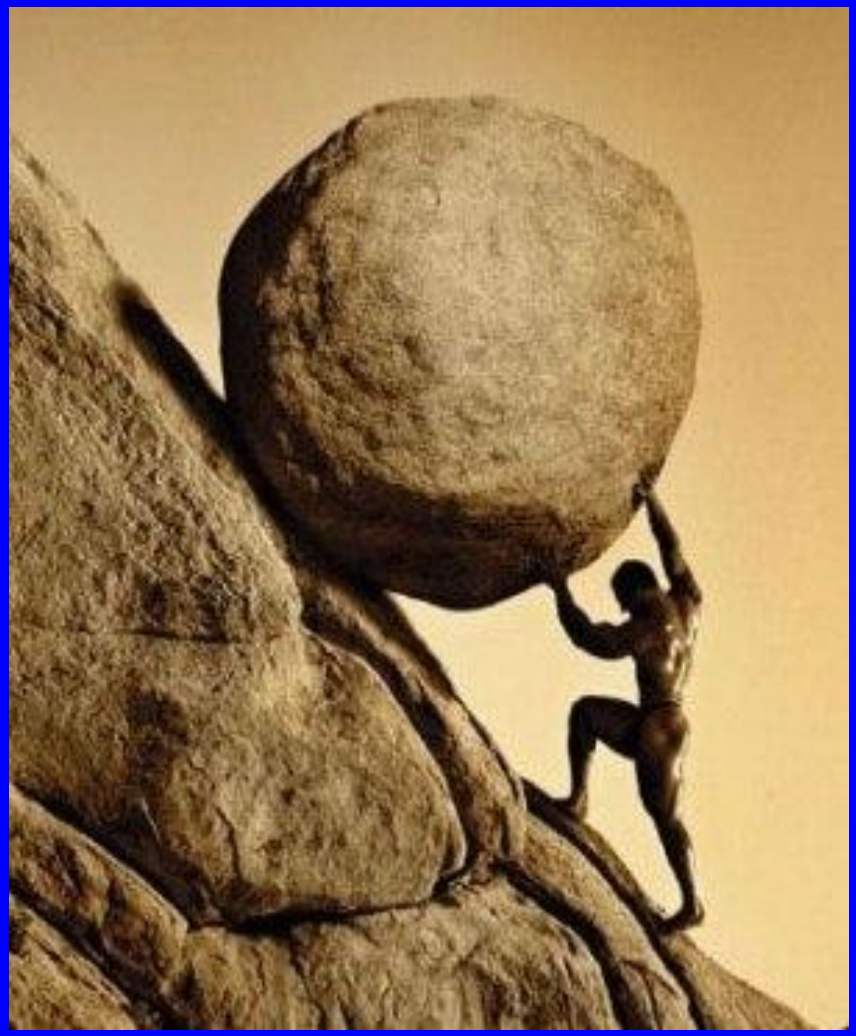
CDP Secretariat 2006



NRC 2008

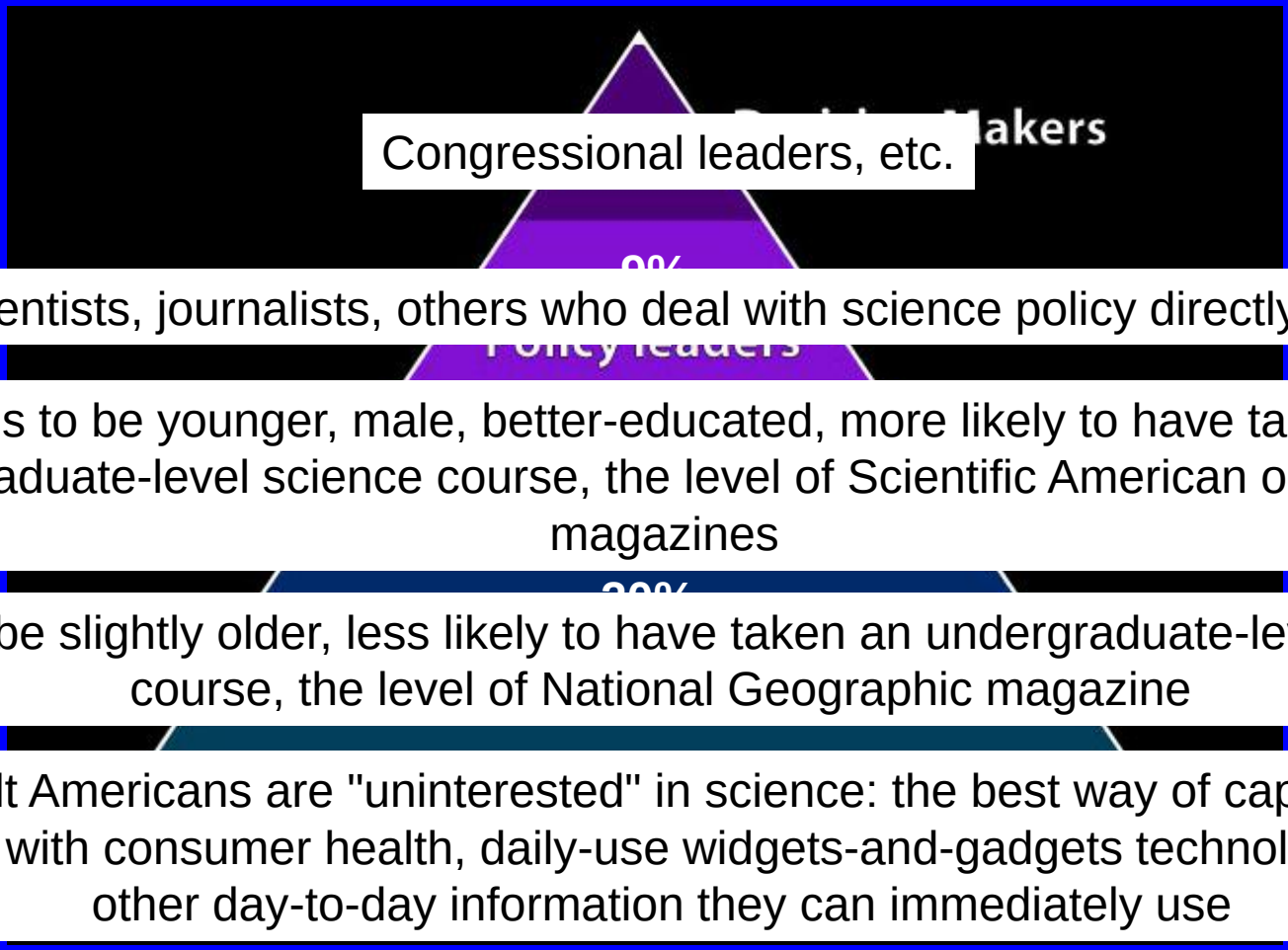
In Light of Evolution, Vol. 2: Biodiversity and Extinction

Challenges



- Diverse stakeholders and agendas
- Quantifying the impact of biodiversity
- Insufficient research effort and infrastructure

Making Sense of a Diversity of Stakeholders



Congressional leaders, etc.

Includes scientists, journalists, others who deal with science policy directly or indirectly

Tends to be younger, male, better-educated, more likely to have taken an undergraduate-level science course, the level of Scientific American or Discover magazines

Tends to be slightly older, less likely to have taken an undergraduate-level science course, the level of National Geographic magazine

Most adult Americans are "uninterested" in science: the best way of capturing their attention is with consumer health, daily-use widgets-and-gadgets technology updates, other day-to-day information they can immediately use

Percentage of Adult Americans

Source: University of Chicago National Opinion Research Center (2006)

Making Sense of a Diversity of Stakeholders

January 23, 2009 New York Times
Environmental Issues Slide in Poll of Public's Concerns
By Andrew C. Revkin

A new poll suggests that Americans, preoccupied with the economy, are less worried about rising global temperatures than they were a year ago but remain concerned with solving the nation's energy problems.

Quantifying Biodiversity

What we know:

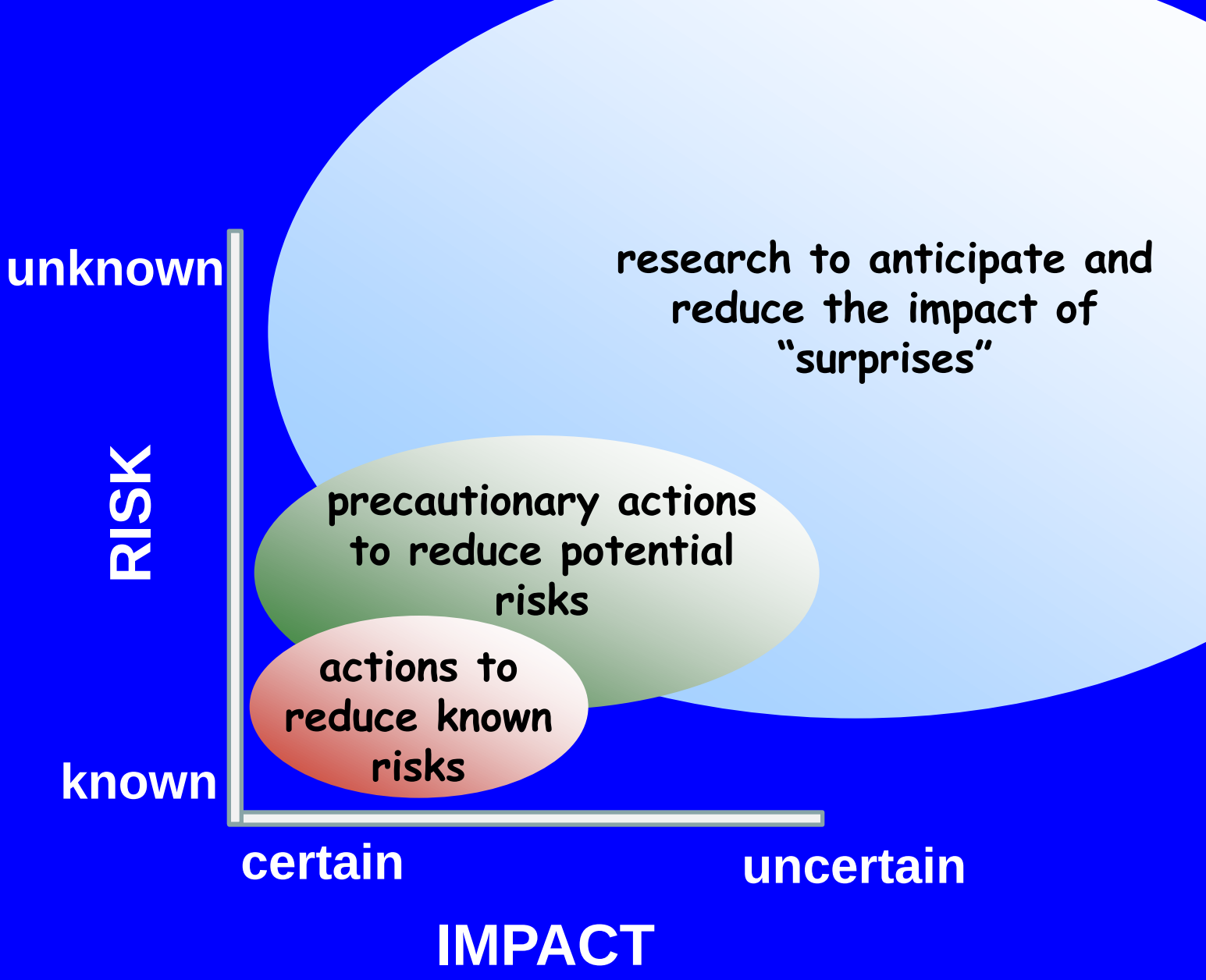
- species are interdependent
- rapid change in biodiversity can have unexpected ecosystem effects
- biota both respond to and drive global change

What we don't know:

- dimensions of biodiversity
- scale effects
- likely tipping points (species loss, ecosystem collapse)

What we need:

- reliable forecasts
- translation of biodiversity to stakeholders

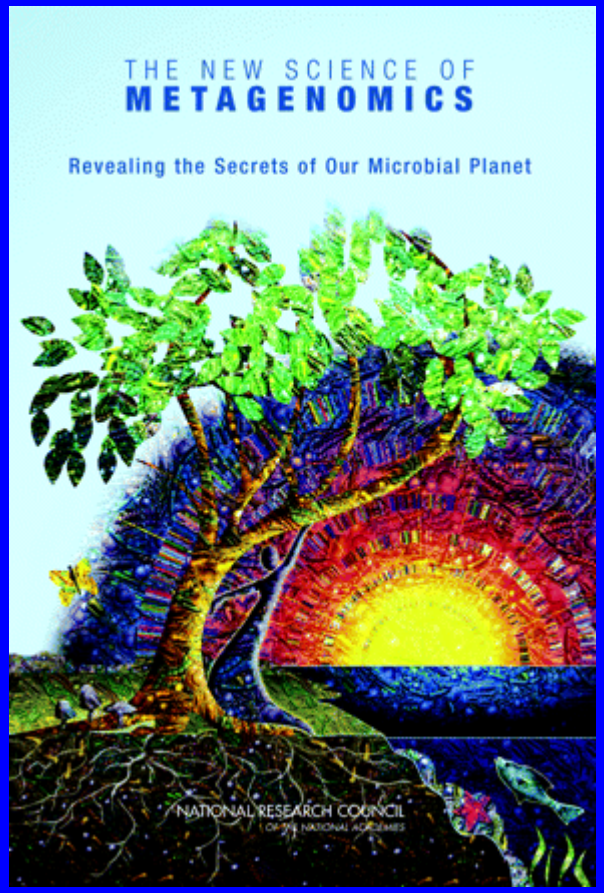


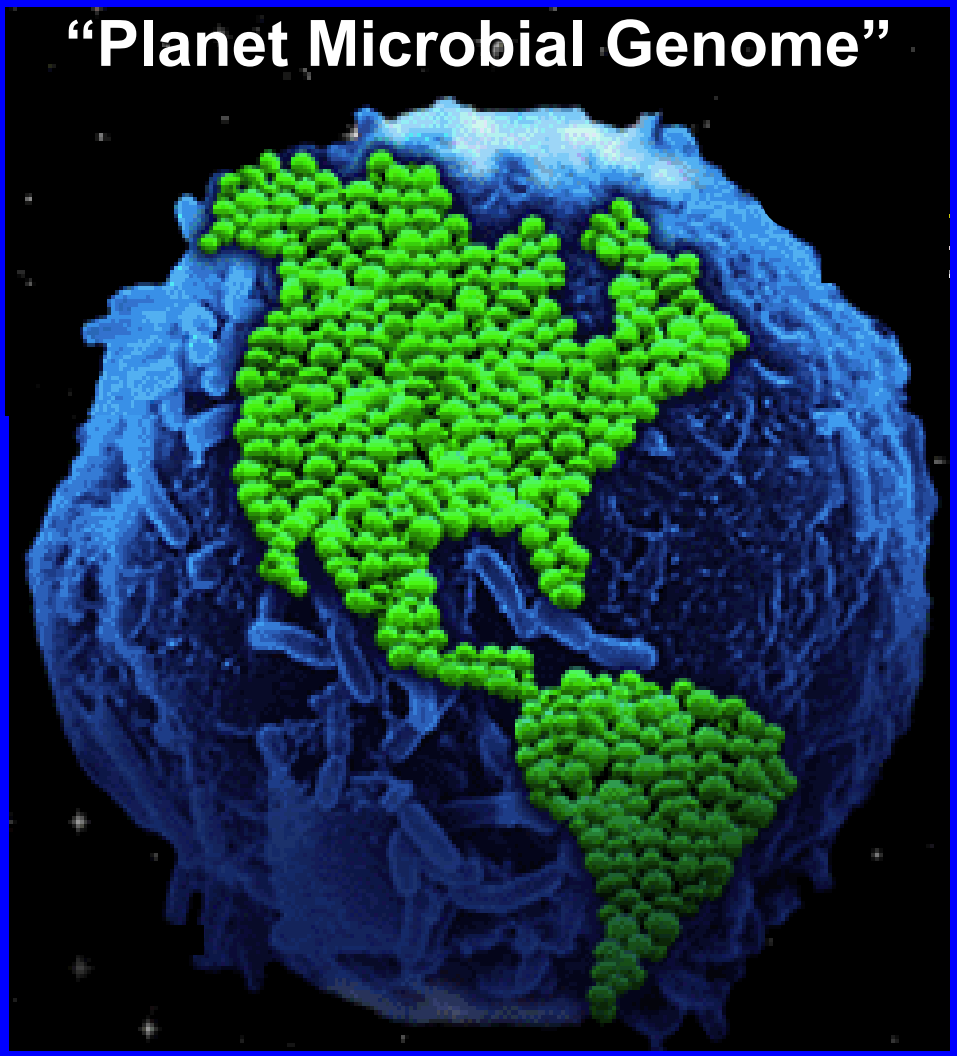
Based on: *Late Lessons from Early Warnings*, European Environment Agency (2001)

Context: *Planetary Change*

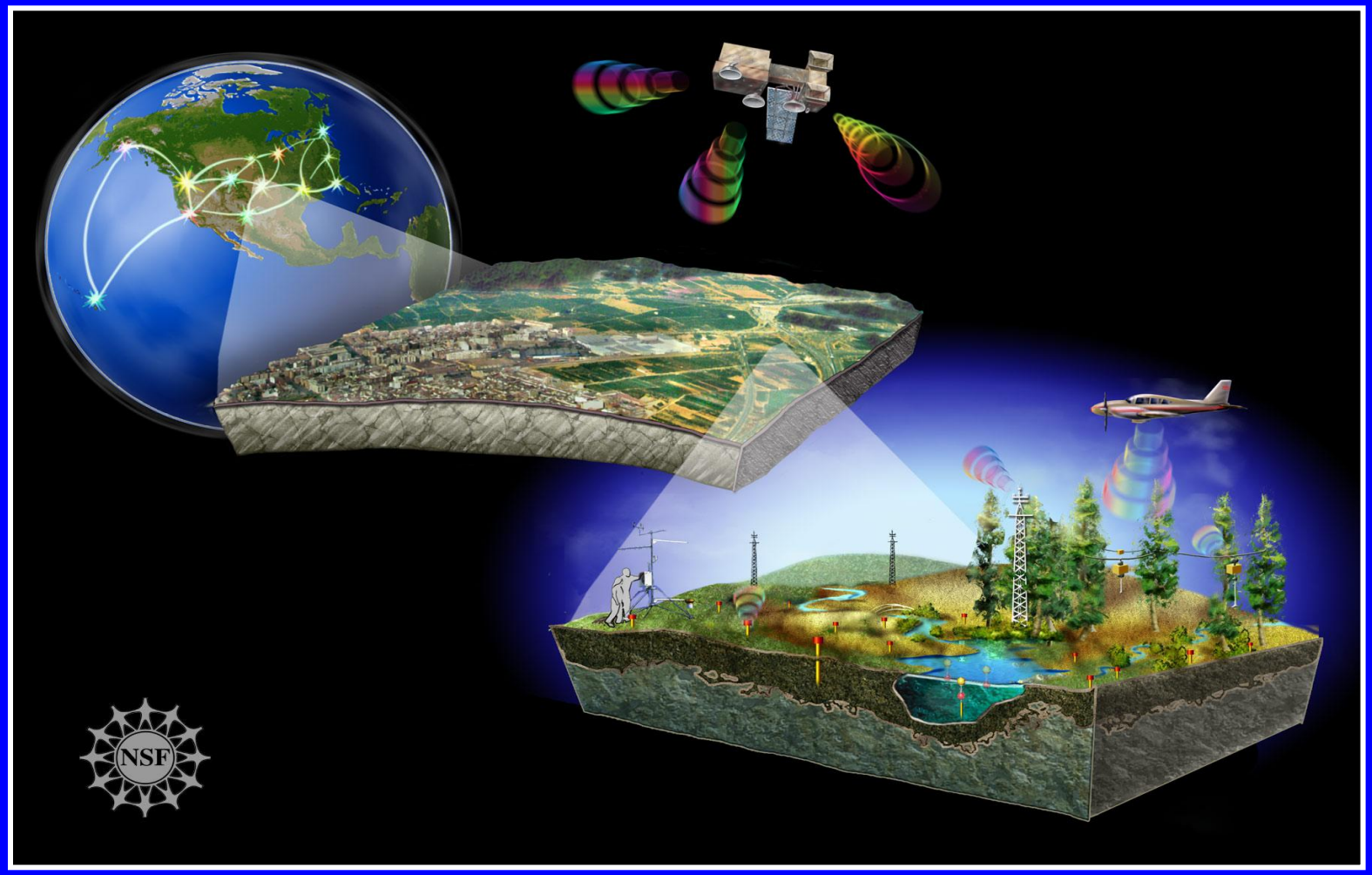
Earth's climate and life support systems are changing in novel and unexpected ways.

Game Changer: *New Tools and Approaches*
Genomics Technologies





Game Changer: *Cyber-Enabled Observatories*



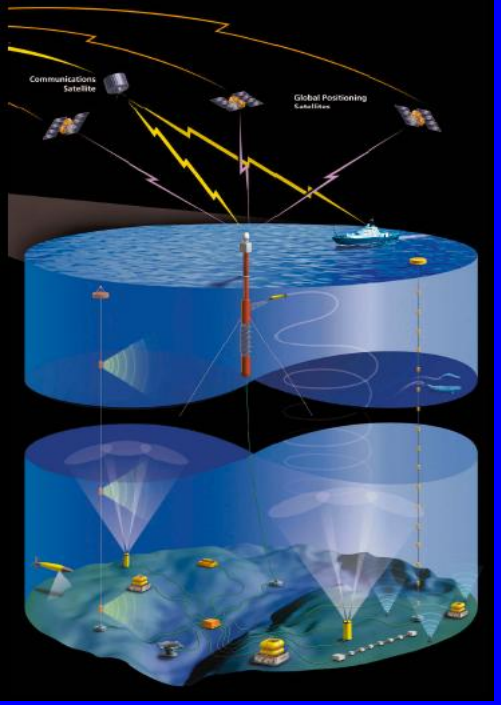
National Ecological Observatory Network (NEON)

Cyber-Enabled Observatories

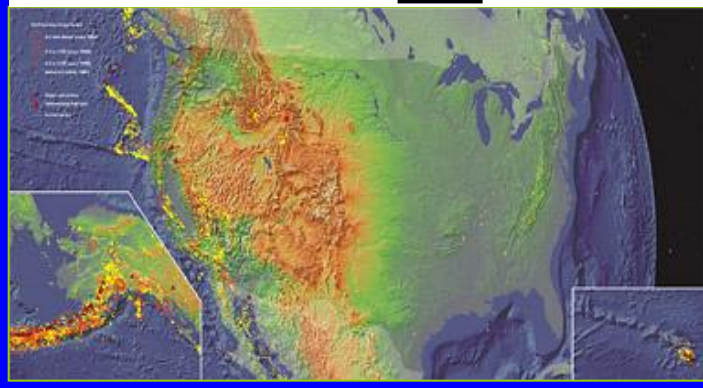
- Hybrid operational and research platforms
- Long-term measurements
- Standardized infrastructure, procedures, quality control
- Free and open data access policy for near real time data
- Decision support tools

ORION

Ocean Research Interactive Observatory Networks



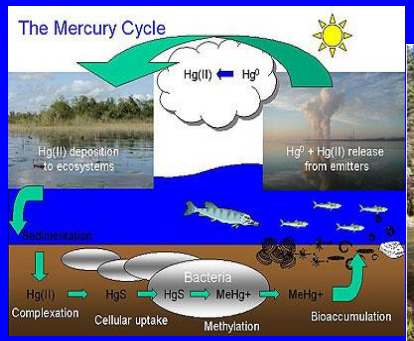
neon



SAFOD USArray PBO InSAR earthscope

New Horizons in Earth Observation

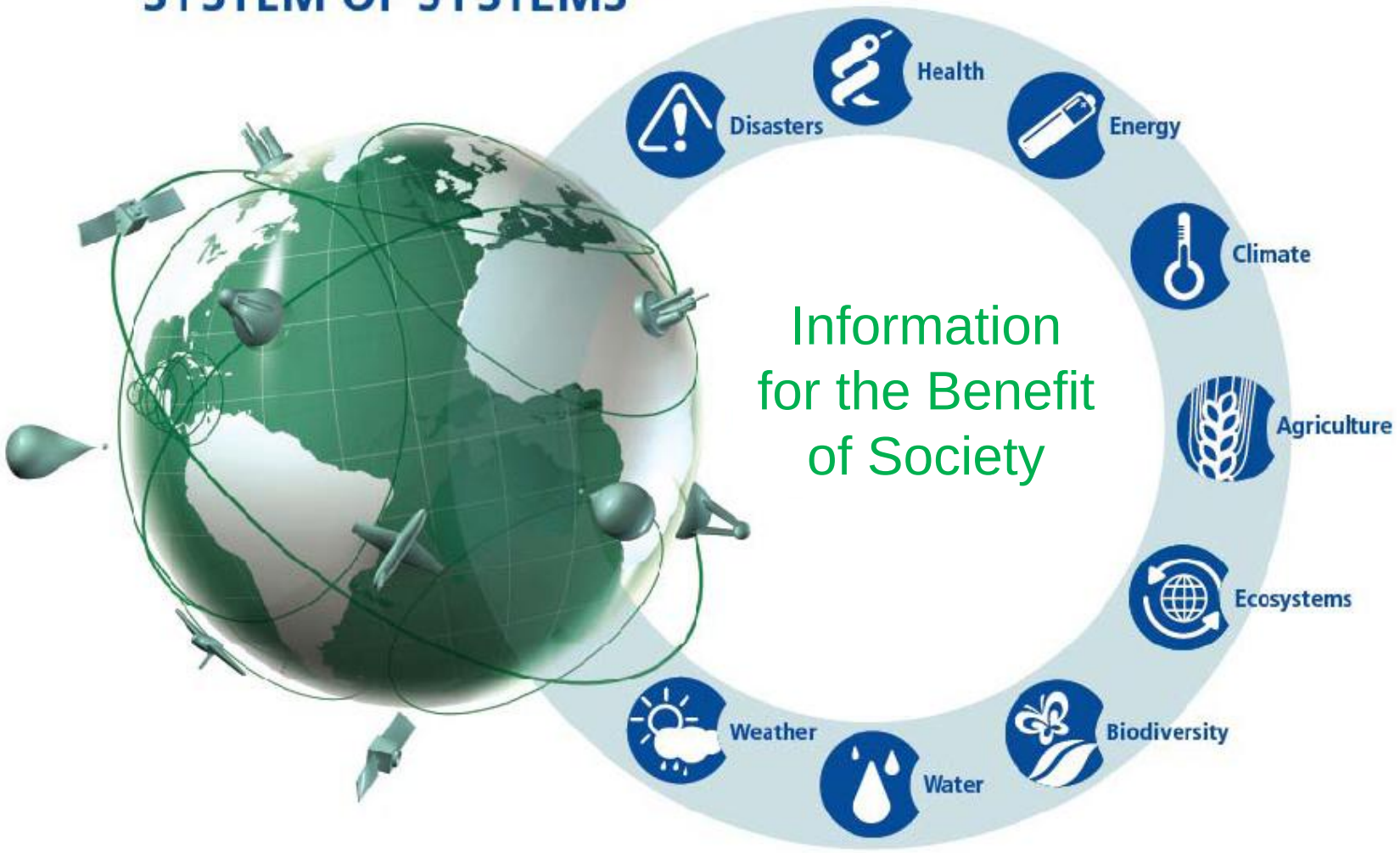
LTER



CUAHSI

Consortium of Universities for the Advancement of Hydrologic Science, Inc.

THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS



Vol 456|18/25 December 2008 nature

COMMENTARY

Three rules for technological fixes

Not all problems will yield to technology. Deciding which will and which won't should be central to setting innovation policy, say Daniel Sarewitz and Richard Nelson

1. **Connect the problem to the solution.**
2. **Assess the effects of biodiversity using relatively unambiguous or uncontroversial criteria.**
3. **Build upon existing standardized approaches.**

We need more research establishing the dimensions, consequences, and societal impacts of biodiversity.

Next Steps

Within a decade: **What are the dimensions of biodiversity?**

Inventory of the Biosphere

Will DNA barcoding advance efforts to conserve biodiversity more efficiently than traditional taxonomic methods?

Introduction: Anthony I Cognato and Ryan M Caesar
Two views: Mark Blaxter and Alfried P Vogler

Next Steps

Within a career: What are the consequences of species loss?

The Biology of Extinction

Demographic models and IPCC climate projections predict the decline of an emperor penguin population

Stéphanie Jenouvrier[a,b,1], Hal Caswell[a,1], Christophe Barbraud[b], Marika Holland[c], Julienne Strœve[d], and Henri Weimerskirch[b]

PNAS Early Edition Jan 26 2009

Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change

Stephen E. Williams*, Luke P. Shoo, Joanne L. Isaac, Ary A. Hoffmann, Gary Langham

PLoS Biol December 2008 | Volume 6 | Issue 12 | e325

Biology of extinction risk in marine fishes

John D. Reynolds[1,*], Nicholas K. Dulvy[2], Nicholas B. Goodwin[3] and Jeffrey A. Hutchings[4]

Proc. R. Soc. B (2005) 272, 2337–2344

Next Steps

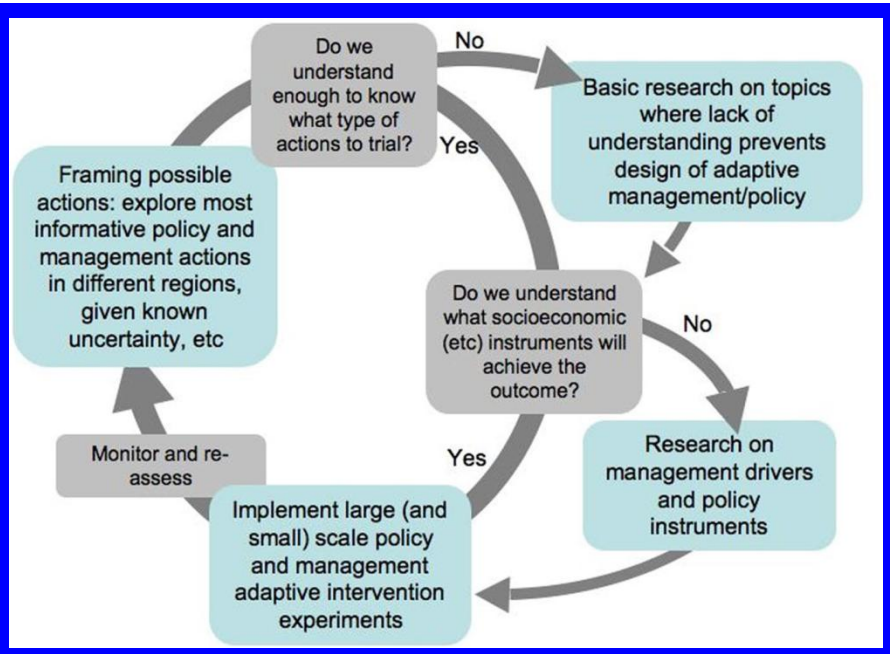
Within a generation: **What information is needed to represent ecosystem services accurately in national accounts?**

The Dynamics of Coupled Natural and Human Systems

Interdisciplinary research for managing ecosystem services

Will Steffen[1]

PNAS **February 3, 2009 vol. 106 no. 5 1301–1302**



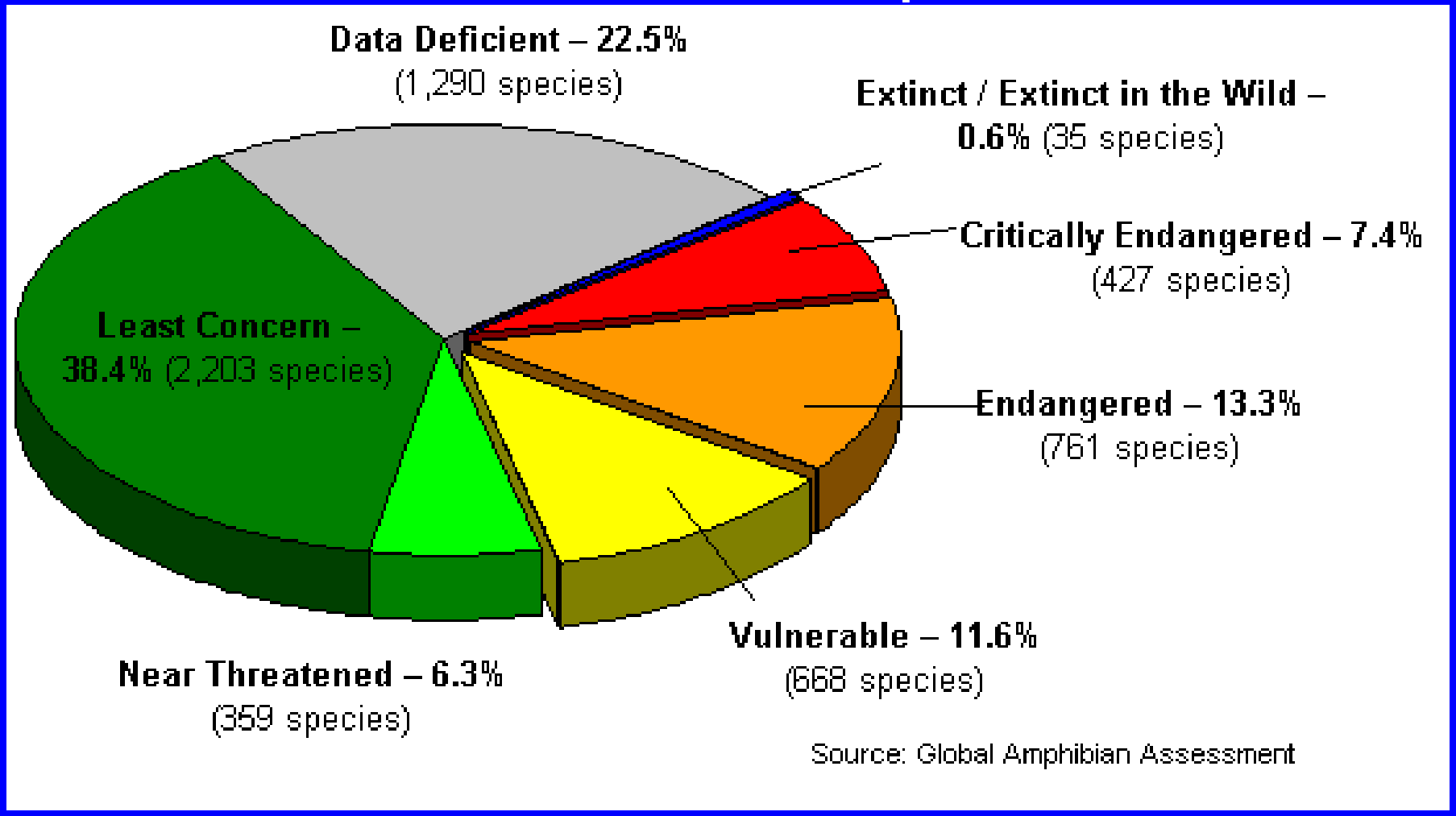
Next Steps

- **The Academy:**
  - **Value research that is discovery-based as well as research with a strong theoretical/conceptual basis**
  - **Reward “team driven” as well as individual research achievement**

- **Biodiversity Research Community:**
  - **Adopt open source biodiversity information and rapid posting of new data**
  - **Develop and adopt new technologies for biodiversity assessment**

Case study: Global amphibian decline

IUCN Red List status for amphibians



Extinction rate of amphibians is about 200 times the historical background extinction rate (McCallum 2007, Roelants et al. 2007)

Suspected causes of amphibian declines and extinction

Historic

- Commercial use
- Introduced species
- Land use change

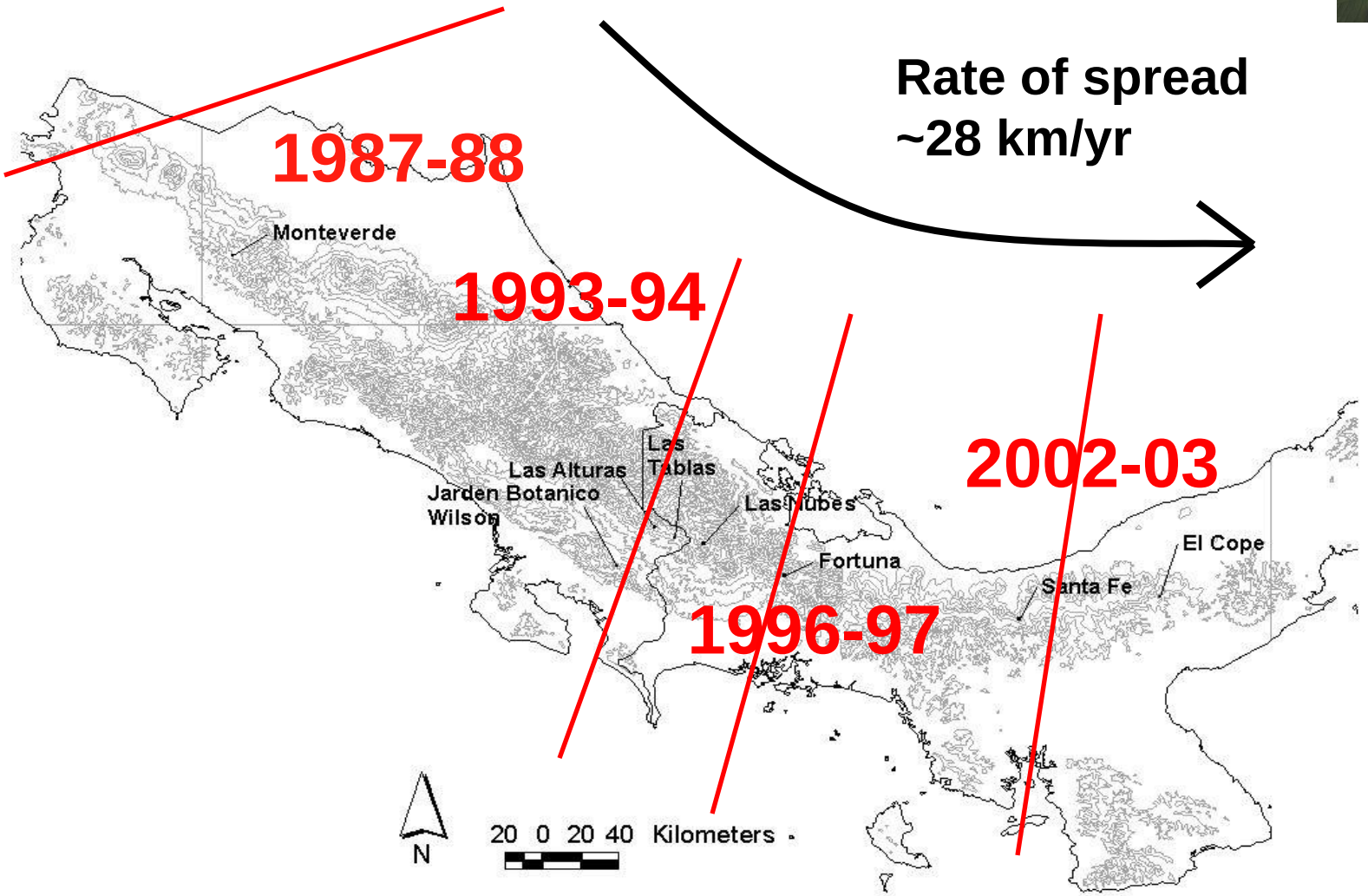
Recent

- Contaminants
- Infectious diseases
- Climate change

Chytrid - amphibian system

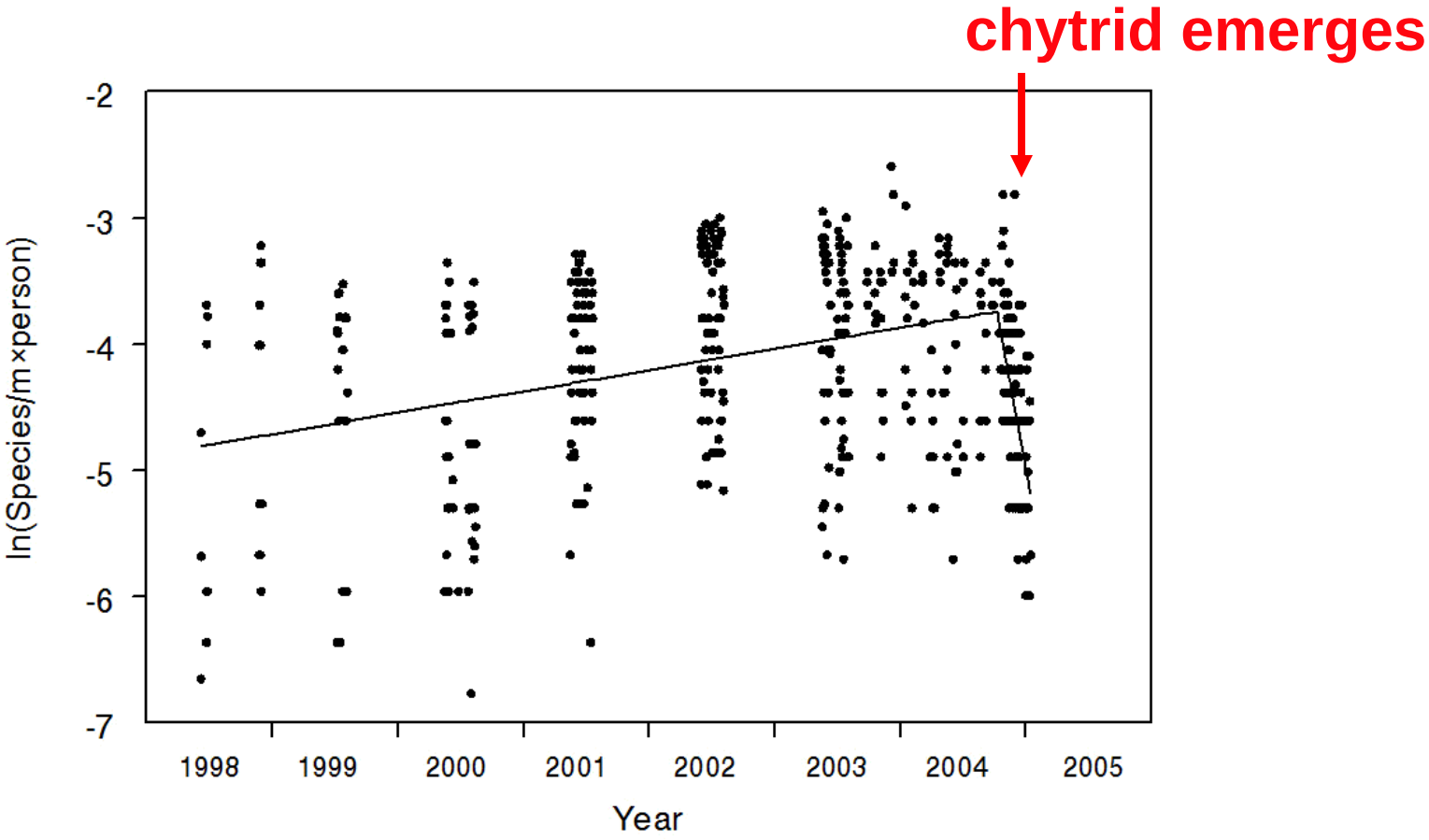
- Chytrid is associated with anuran declines and extinctions in Australia, Africa, Central, South, and North America, but also coexists with non-declining species.
- It infects most amphibian species tested with effects varying from no clinical disease to 100% mortality.
- Microenvironment affects susceptibility to chytrid.

Population sizes and species richness of amphibian communities decrease as amphibian chytrid spreads



Source: Lips et al. 2006, PNAS. Infectious disease and global biodiversity loss: pathogens and enigmatic amphibian extinctions.

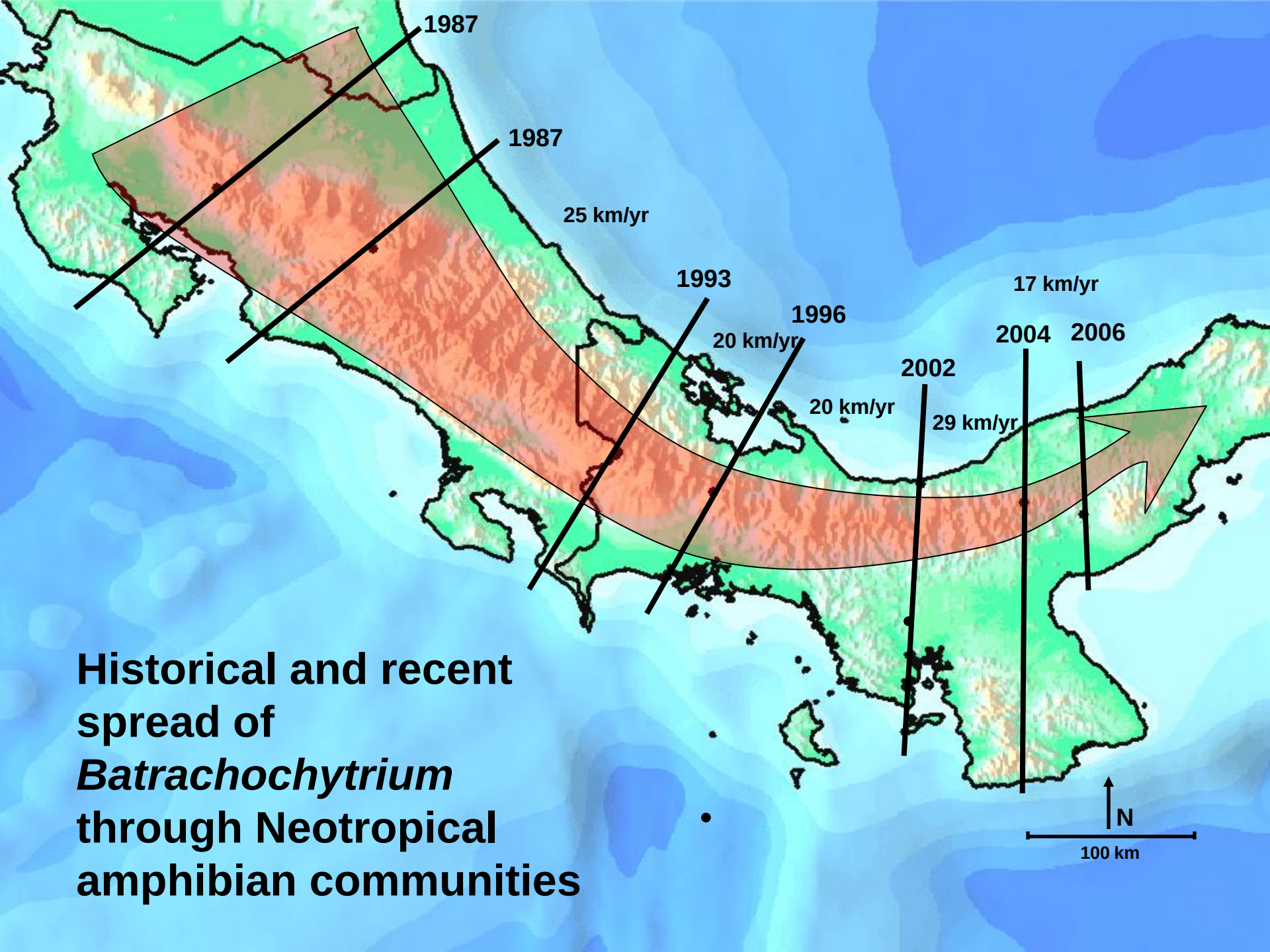
Amphibian species changes along streams



Amphibian species richness and segmented linear models for riparian and terrestrial transects (1998 – 2005) at El Cope, Panama. There was a highly significant change in slope for riparian transects ($\theta 2$ = -6.45×10-3, t = -6.97, df = 486, P < 0.0001) but not for terrestrial transects ($\theta 2$ = -3.77×10-3, t = -1.78, df = 212, P = 0.0757).

Central American pattern of declines

- 50% of species gone in 4-6 months
- Remaining species are at 10% of abundance
- Pattern not consistent with land use change, exotic species, commercial use, climate change, or contaminants



Historical and recent spread of *Batrachochytrium* through Neotropical amphibian communities

What policy and ethical implications follow from understanding the process of extinction?

AN AMPHIBIAN CONSERVATION ACTION PLAN

AMPHIBIAN CONSERVATION SUMMIT

IUCN
The World Conservation Union

Amphibian Conservation Action Plan

Proceedings: IUCN/SSC Amphibian Conservation Summit 2005

Edited by Claude Gascon, James P. Collins, Robin D. Moore,
Don R. Church, Jeanne E. McKay and Joseph R. Mendelson III

IUCN Species Survival Commission

ASG
IUCN/SSC
Amphibian
Specialist Group

CONSERVATION
INTERNATIONAL

SSC
Species Survival Commission

BIODIVERSITY

Confronting Amphibian Declines and Extinctions

Stopping further global losses of amphibian populations and species requires an unprecedented conservation response.

Joseph R. Mendelson III,* Karen R. Lips, Ronald W. Gagliardo, George B. Rabb, James P. Collins, James E. Diffendorfer, Peter Daszak, Roberto Ibáñez D., Kevin C. Zippel, Dwight P. Lawson, Kevin M. Wright, Simon N. Stuart, Claude Gascon, Hélio R. da Silva, Patricia A. Burrowes, Rafael L. Joglar, Enrique La Marca, Stefan Lötters, Louis H. du Preez, Ché Weldon, Alex Hyatt, José Vicente Rodriguez-Mahecha, Susan Hunt, Helen Robertson, Brad Lock, Christopher J. Raxworthy, Darrel R. Frost, Robert C. Lacy, Ross A. Alford, Jonathan A. Campbell, Gabriela Parra-Olea, Federico Bolaños, José Joaquin Calvo Domingo, Tim Halliday, James B. Murphy, Marvalee H. Wake, Luis A. Coloma, Sergius L. Kuzmin, Mark Stanley Price, Kim M. Howell, Michael Lau, Rohan Pethiyagoda, Michelle Boone, Michael J. Lannoo, Andrew R. Blaustein, Andy Dobson, Richard A. Griffiths, Martha L. Crump, David B. Wake, Edmund D. Brodie Jr.

The Panamanian Golden Frog, *Atelopus zeteki*, is nearly extinct in the wild as a combined result of habitat change, illegal collecting, and fungal disease; the species is currently secure in several ex situ programs.

Amphibian declines and extinctions are global and rapid: 32.5% of 5743 described species are threatened, with at least 9, and perhaps 122, becoming extinct since 1980 (*1*). Species have disappeared across the entire taxonomic group and in nearly all regions of the planet. These figures are probably underestimates as entire clades of species are threatened. For example, of the 113 species of harlequin toads (genus *Atelopus*), 30 are possibly extinct, and only 10 have stable populations (*2*). Nearly a quarter of known amphibian species were deemed "data-deficient" with respect to conservation status in the recent global assessment (*1*). Losing biodiversity at this taxonomic

ians and to garner and administer funds. Thus, we call for formation of The Amphibian Survival Alliance (ASA)—led by an international secretariat of the Amphibian Specialist Group of the Species Survival Commission of IUCN (World Conservation Union). An initial 5-year budget requires at least U.S.$400 million.

Conservation activities should remain in affected countries where possible, with coordination and support through ASA, to engage and employ local scientists. A special initiative would be regional centers for disease research and captive breeding. Centers would exist within government agencies, zoos, or universities and would be staffed by local scientists,

stakeholders from the academic, conservation, zoo, ethics, policy, global change, private sector, and international biodiversity convention communities uniting for one goal. Support from individuals, governments, foundations, and the wider conservation community is essential.

Policy recommendations for a global action plan

1. ***Research.*** **Improve our understanding of the causes of declines and extinctions**

2. ***Assessment.*** **Document amphibian diversity, and how it changes**

3. ***Conservation.*** **Develop and implement long-term conservation programs**

4. ***Response.*** **Intervene when declines are detected**

To Stem Widespread Extinction, Scientists Airlift Frogs in Carry-On Bags

New York Times; June 6, 2006

By BRENDA GOODMAN

ATLANTA, June 5 — Of all the things airport security screeners have discovered as they rifle through travelers' luggage, the suitcases full of frogs were a first.

In a race to save amphibians threatened by an encroaching, lethal fungus, two conservationists from Atlanta recently packed their carry-ons with frogs rescued from a Central American rain forest ….

The frogs…were perhaps the last of their kind, collected from a pristine national park that fills the bowl of El Valle, an inactive volcano in Panama.

Ron Gagliardo (left) and Joe Mendelson

Stakeholder values and research questions that confront ecologists and biodiversity managers

- What is the scientific community's role and responsibility given the possible imminent extinction of dozens of species?
- What is the conservation community's role and responsibility?
- What is the zoo community's role and responsibility regarding animal husbandry?

Ecological ethics: Building a new toolkit for ecologists and biodiversity managers

Ecologists and biodiversity managers often encounter complex ethical situations in research and professional activities.

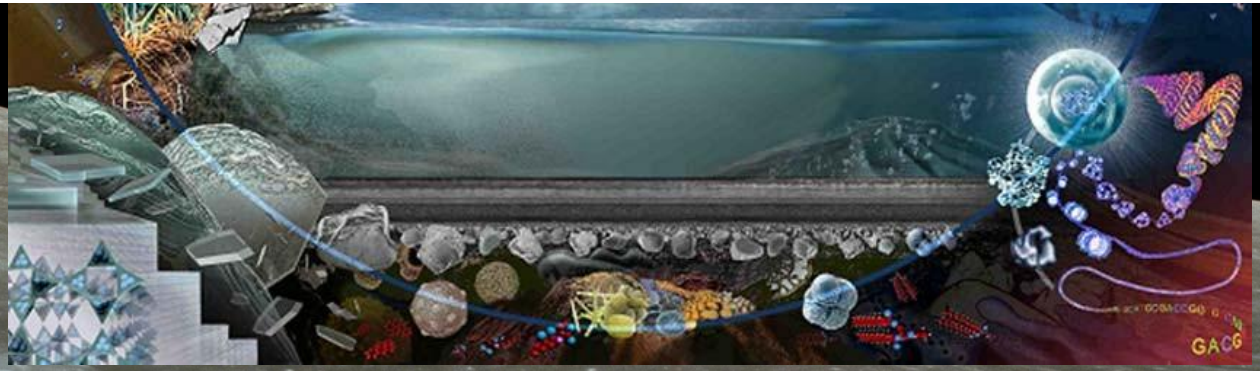
There is currently no field in professional or practical ethics that specifically addresses the unique moral concerns of practicing ecologists and managers relative to research animals, species, and ecological systems, as well as to the scientific profession and the public interest.

A new approach –“ecological ethics” – is needed.

[From: Minteer and Collins. 2005. Conservation Biology]

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us.

From the conclusion of Darwin's Origin of Species, First Edition (1859)



Acknowledgments

Penelope Firth
Maureen Kearney
Charles Liarakos
Joann Roskoski
Daniel Sarewitz
Robert Sterner
Payton Thomas

Enabling the nation's future through discovery, learning and innovation

Back up slides

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us.

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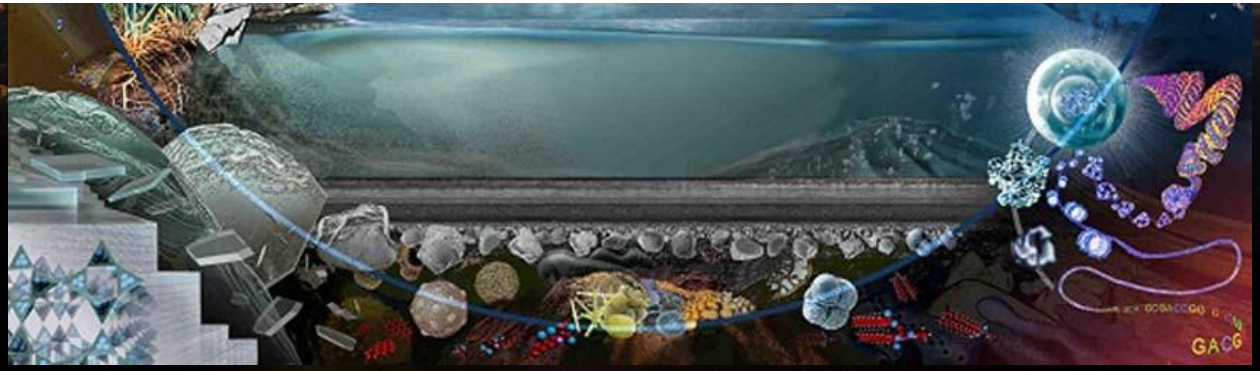


Distribution of species in IUCN Red List categories

Categories	Birds	Mammals	Amphibians
Globally threatened species	1211 12%	1130 23%	1856 33%
Critically endangered species	179 1.8%	184 3.8%	427 7.4%

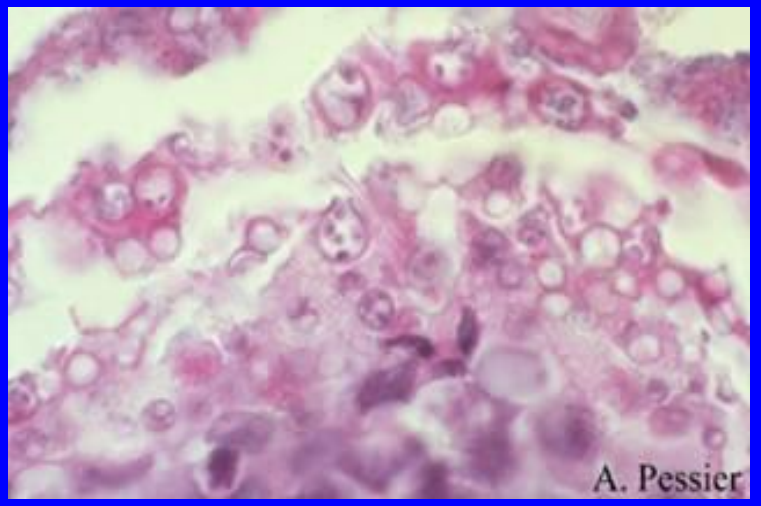
[Source: GAA 2004]

Extinction rate of amphibians is about 200 times the historical background extinction rate (McCallum 2007, Roelants et al. 2007)

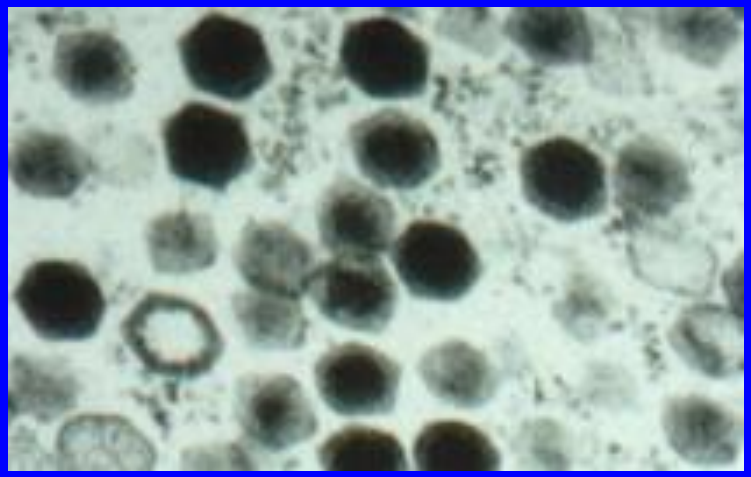
Infectious disease

Two pathogens associated with enigmatic amphibian declines

Chytrid – a fungal pathogen of frogs and salamanders - *Batrachochytrium dendrobatidis (Bd)*



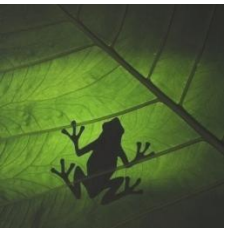
Ranavirus – a genus of viruses infecting cold blooded vertebrates



Stakeholder values and research questions that confront ecologists and biodiversity managers

What are the administrative and policy communities' roles and responsibilities in this case?

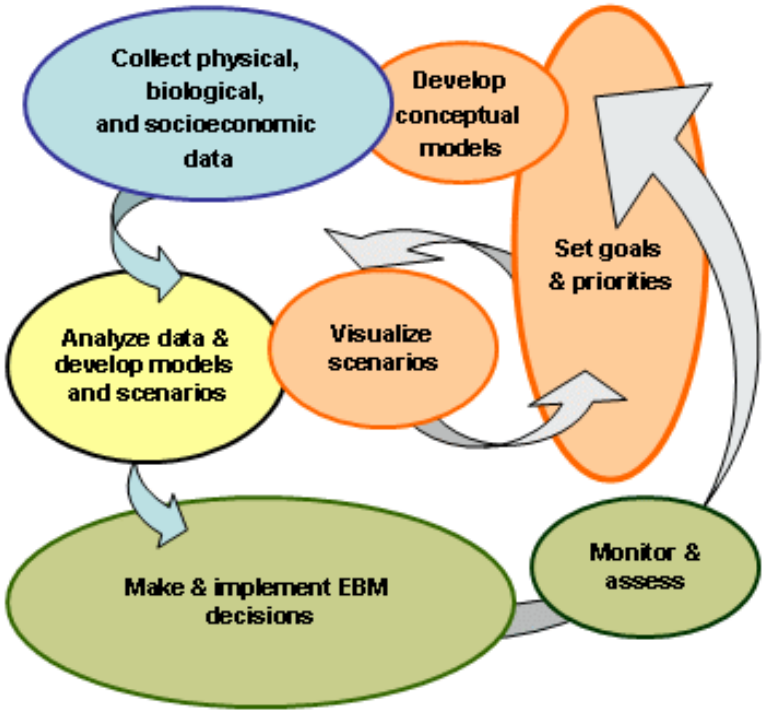
For example, should the government close and isolate the central Panamanian forest reserves with endangered frog species for fear that people may transmit the pathogen?



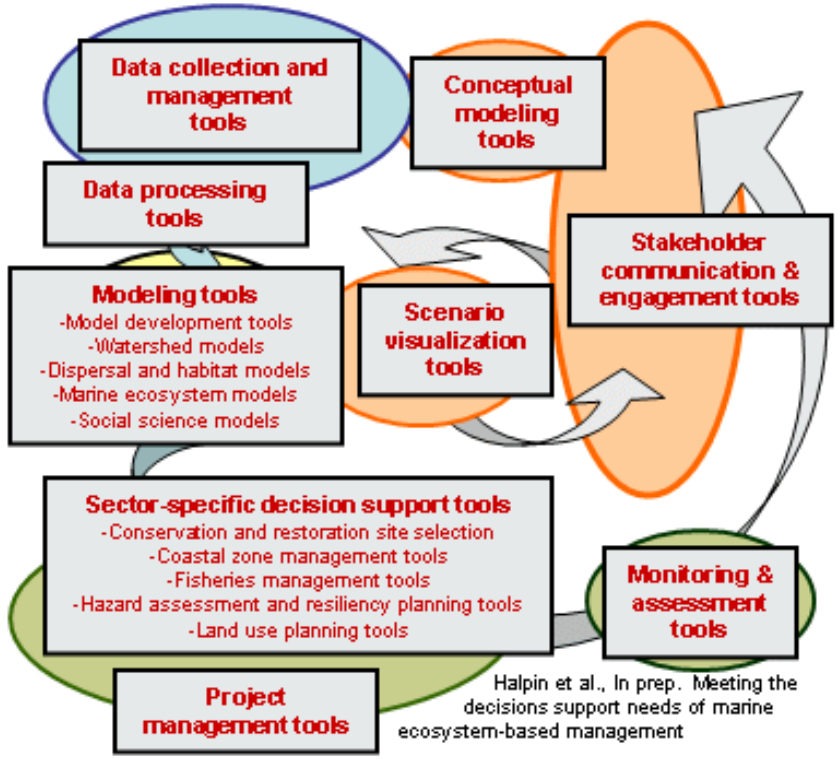
Game Changer: *Adaptation*

Transformations and Transitions in the Story of Life

Decision Support Tools



http://www.ebmtools.org/about_ebm_tools.html



Halpin et al., In prep. Meeting the decisions support needs of marine ecosystem-based management

Innovation Seen As Key To Curbing Climate Change

NPR Morning Edition, February 4, 2009
Richard Harris interview of Dr. Dan Sarewitz, Arizona State University

Some experts say President Obama's goal to cut emissions by 80 percent by 2050 isn't enough to curb global warming.

The Obama administration has very ambitious plans for confronting climate change: billions of dollars targeted toward energy and climate in the stimulus package are just a tiny down payment.

Sarewitz argues that the way forward on climate change requires innovation and institutions *a la* how the US transformed agriculture by creating a continued commitment to productive growth.

Context: *Integrating Scales*

Living systems shape Earth's environment across scales of time, place and size

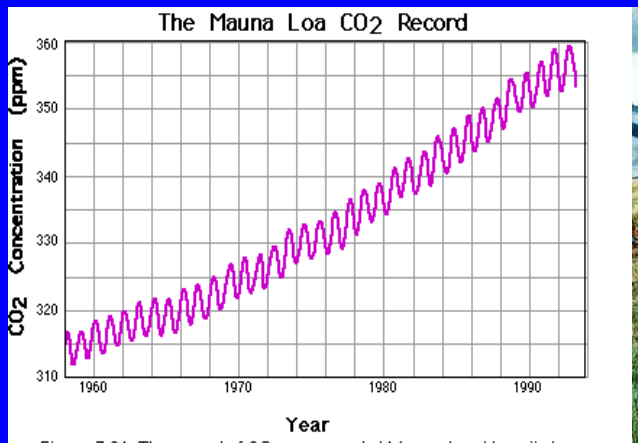
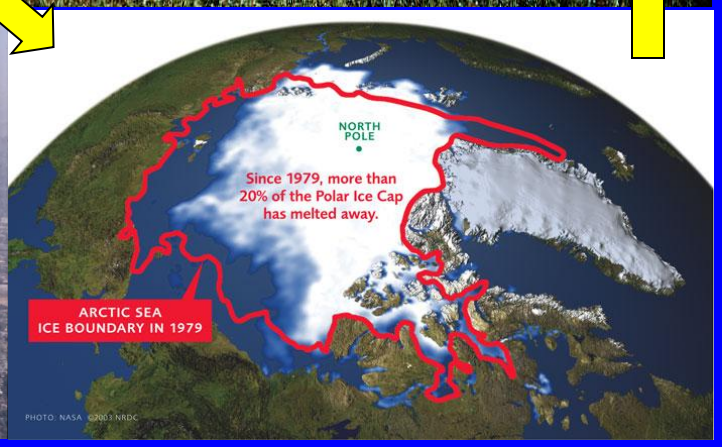


Figure 7.01 The record of CO_2 measured at Mauna Loa, Hawaii shows seasonal cycles — related to the activity of plants in the Northern Hemisphere — on top of an increasing trend to higher values. The record also shows a subtle increase in the seasonal amplitude over time.

CH_4

CO_2



Reasoning by Analogy: Three rules for technological fixes

- **Connect the problem to the solution.**
- **Assess the effects of biodiversity using relatively unambiguous or uncontroversial criteria.**
- **Build upon existing standardized approaches.**

We need more research establishing the dimensions, consequences and societal impacts of biodiversity.

Researchers, Educators, and Policymakers
Contrasting Cultures and Different Aims

Henri Matisse

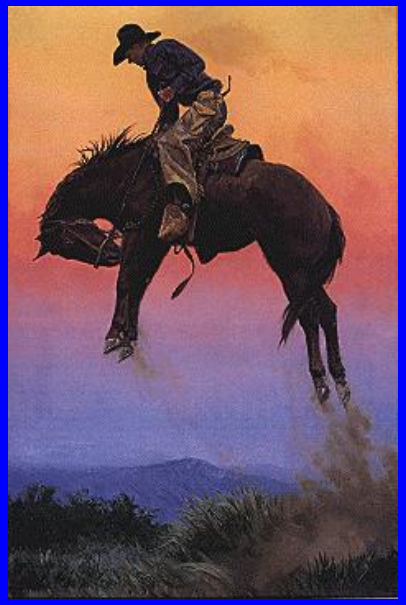
Contrasting Cultures

Rational	Subjective values
Facts & Evidence	Perceptions & Beliefs
Proof	Emotions
Measurements	Deadlines
Incremental Progress	Crises

Different Aims

Discovery
Understanding
Enlightenment

Action!



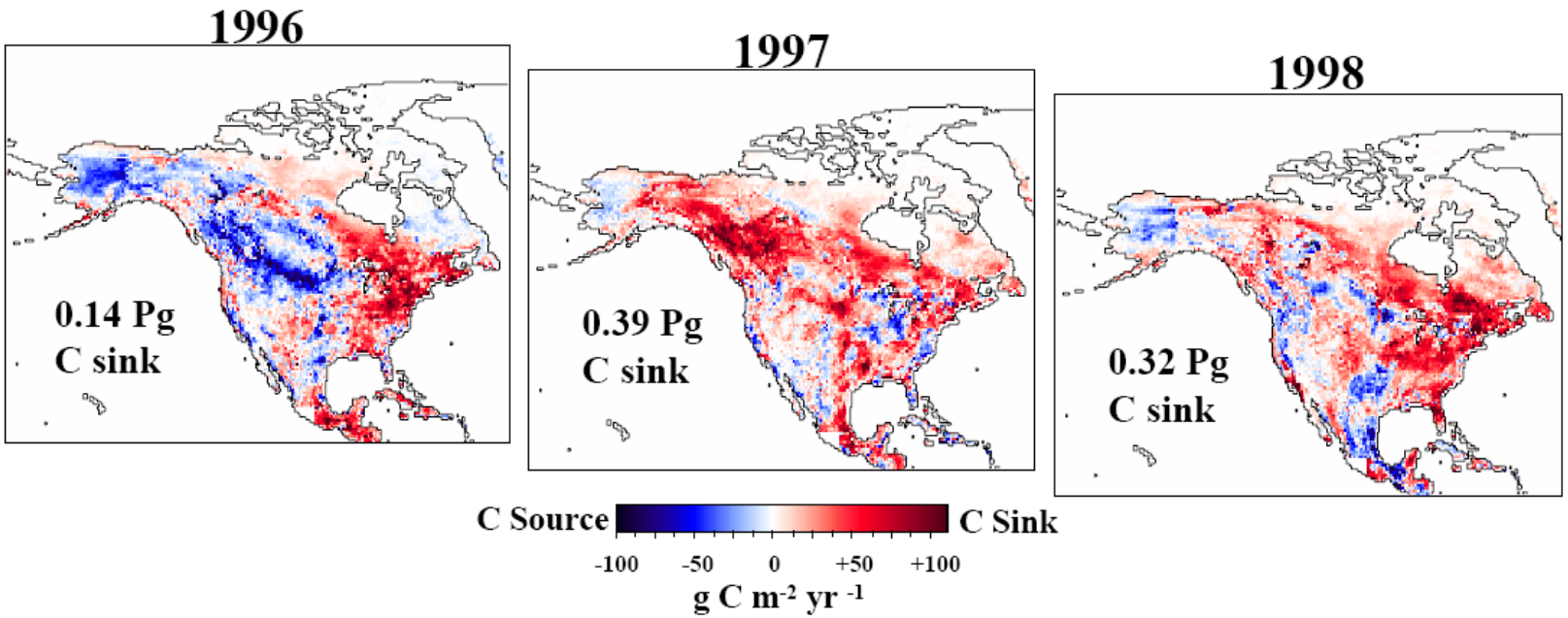
Bill Owen

Research & Education

Decision Making

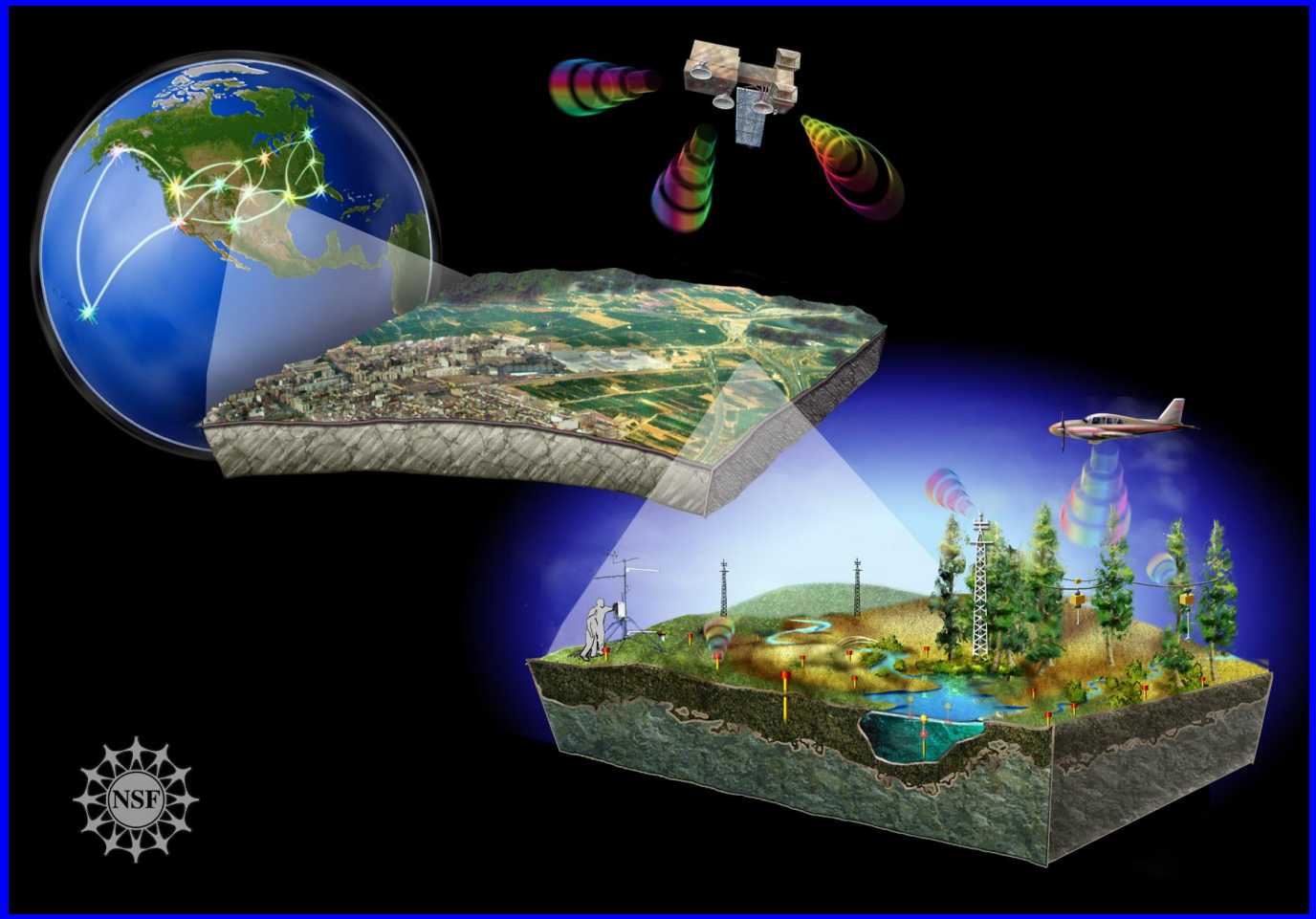
Prediction of the North American Carbon Sink

Potter et al. 2003 "The North America Carbon Sink from 1982-1998 Estimated using MODIS Algorithm Products"



- **Dramatic inter-annual variation is not totally explained by physical factors (temperature, rainfall)**
- **Do biological processes determine/impact this variation?**
- **Which ones, how and how much?**
- **Can knowing life's impacts on the system improve predictions? Inform carbon trading scenarios?**

Game Changer: New Horizons in Earth Observation
Cyber-Enabled Research Observatories



The National Ecological Observatory Network (NEON) is a continental-scale infrastructure platform designed to investigate the ecological effects of invasive species, climate, and land-use change.

Making Connections…

Multidisciplinary Programs

Dynamics of Coupled Natural and Human Systems

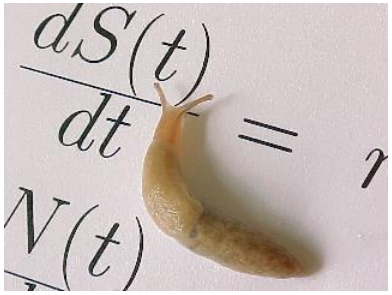
[BIO, GEO, SBE, & USFS]

Ecology of Infectious Diseases

[BIO, GEO, SBE, & NIH]

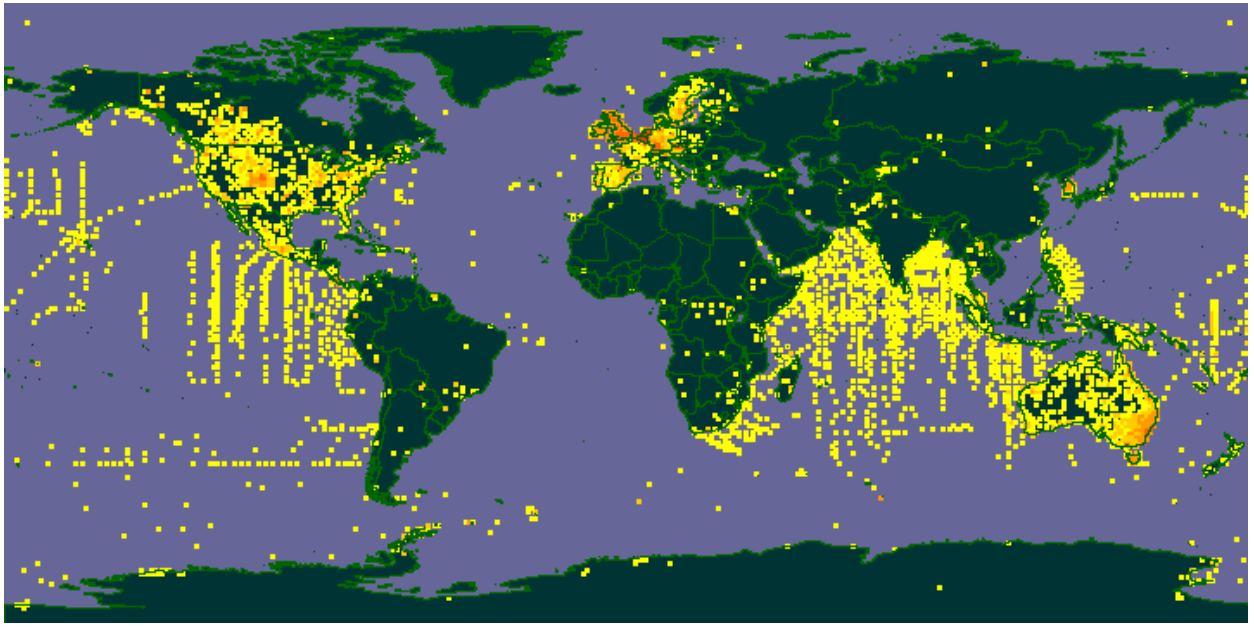
Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences

[BIO, EHR, & MPS]



Understanding the Dimensions of Biodiversity

We are the first generation of scientists with the tools to address the dimensions of biodiversity on Earth…
And we may be the last generation with the opportunity to discover and understand Earth's biodiversity before it is irrevocably changed or lost.



Too interconnected to fail

Grand Challenge: Foresee and forestall catastrophic change in the biosphere

Strategies:

More experts: scientists and educators

Improved access to data (digital collections)

Global connectivity

Integration across disciplines

Education

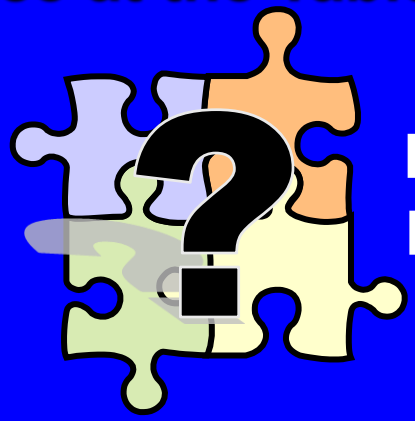
Public communication and engagement

Inform decision makers

A Place at the Table

Curiosity
Potential benefits
National needs
. . .

Science Policy



Public Policy

Values
Perceptions
Beliefs
Deadlines
Costs
Crises
. . . . . .
Scientific findings

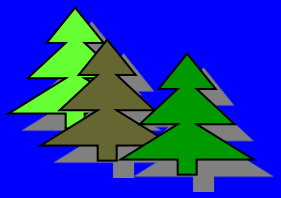
RESOURCES

Science & Engineering Enterprise

INFORMATION & PRODUCTS

Biodiversity Discovery & Understanding

Analysis – Synthesis – Education - Prediction – Assessment – Scenarios & Options



Integration with related disciplines

Information Access

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us.

From the conclusion of Darwin's Origin of Species, First Edition (1859)