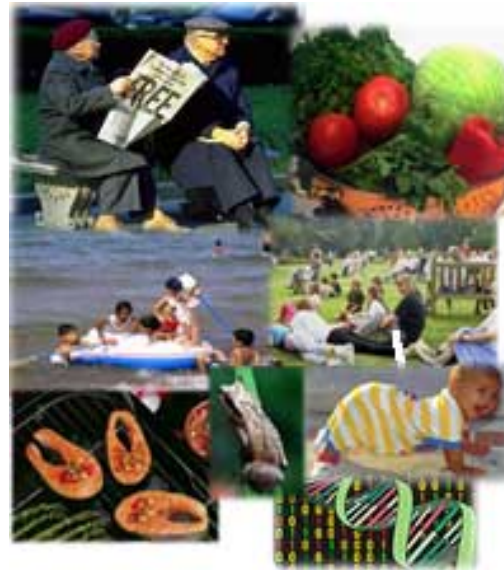


Examining the Links Between Biodiversity and Human Health: A New Interdisciplinary Initiative



Montira Pongsiri, PhD, MPH
U.S. Environmental Protection Agency
COHAB 2
28 February 2008

Outline

- Background
- Interdisciplinary Approach
- Leading Research Questions
- Research Projects – Extramural and Interagency
- Expected Results

Ecosystem Services

As provided by the diversity of life on earth

Provisioning Services

Food
Freshwater
Wood and fiber
Fuel
Clean Air
Medicines

Regulating Services

Climate regulation
Flood regulation
Disease regulation
Water purification

Cultural Services

Aesthetic
Cultural
Recreational
Spiritual

Supporting Services

Nutrient cycling
Primary production
Soil formation

Biodiversity loss is accelerating

Fig. 4: TERRESTRIAL LIVING PLANET INDEX, 1970-2003

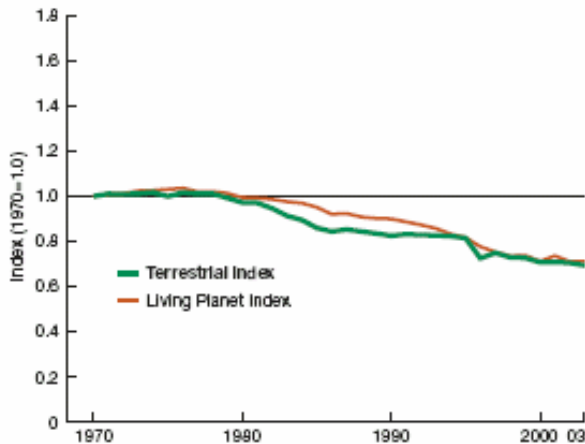


Fig. 5: MARINE LIVING PLANET INDEX, 1970-2003

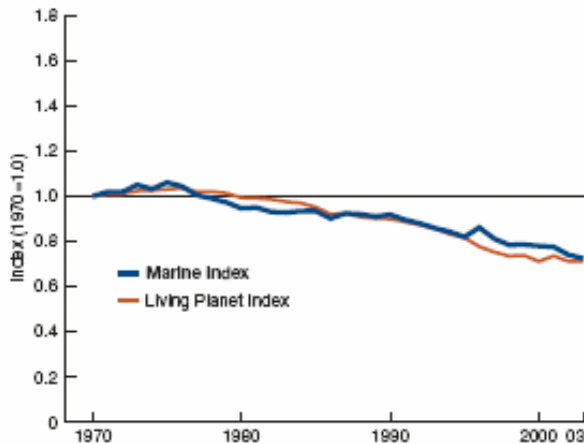
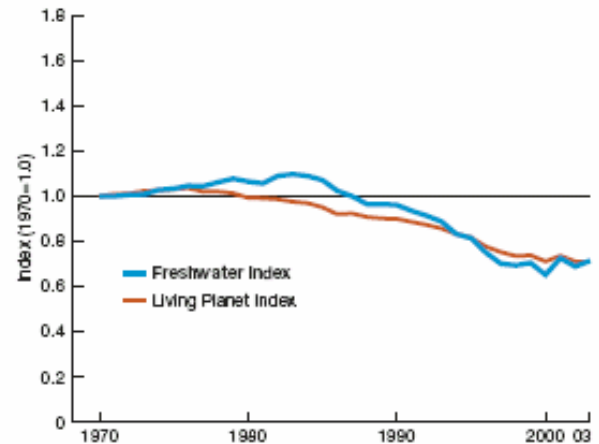


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From WWF, "Living Planet Report," 2006.

BBC NEWS
 Tuesday, 21 May, 2002, 13:48 GMT 14:48 UK
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 Siberian tigers may vanish within three decades
 By Corinne Podger
 BBC science correspondent
 Almost a quarter of the world's mammals face extinction within 30 years, according to a United Nations report on the state of the global environment.

CNN.com / SCI-TECH
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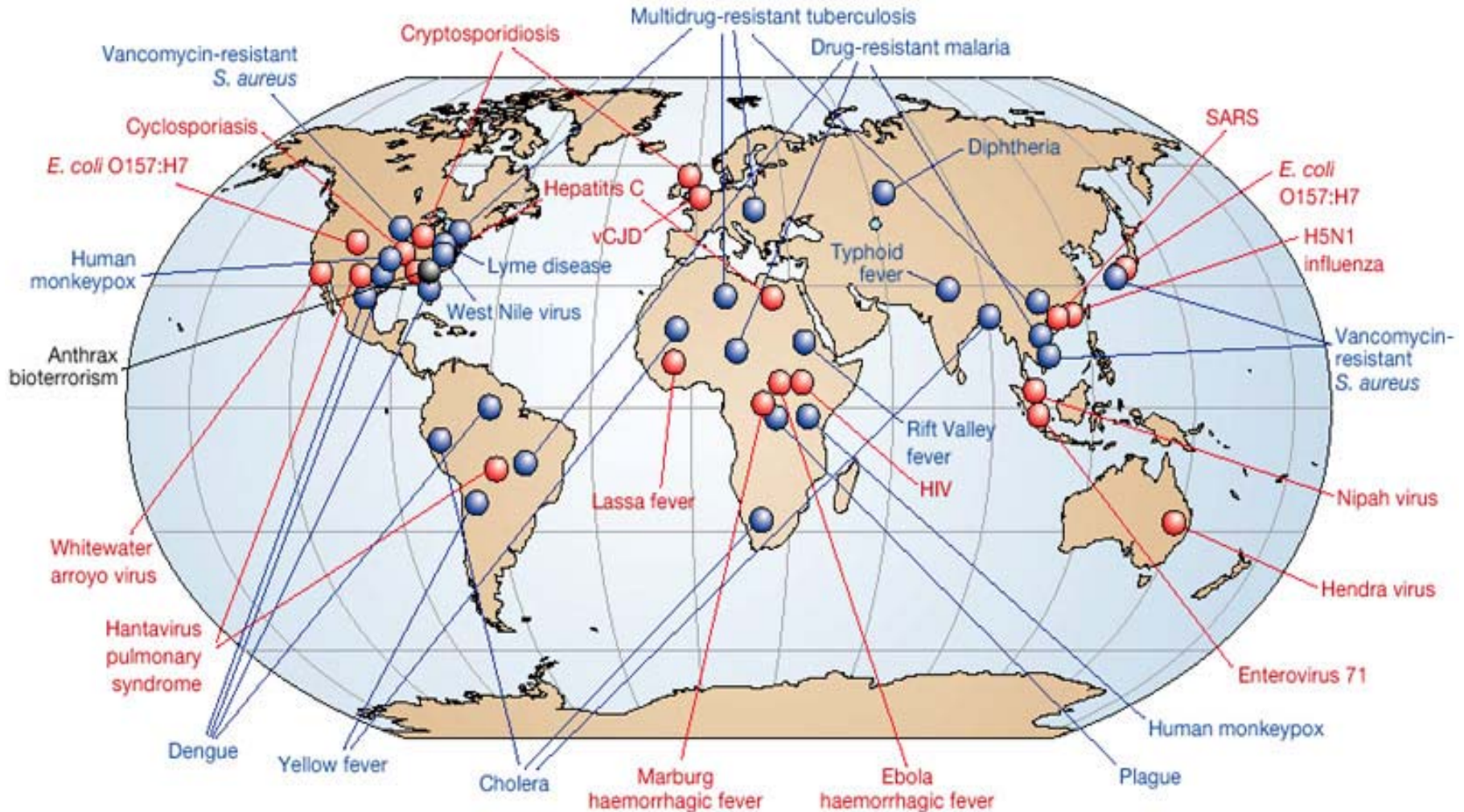
 Organ Pipe Cactus National

CNN.com / SCIENCE & SPACE
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Infectious diseases appear to be emerging and re-emerging at a faster rate

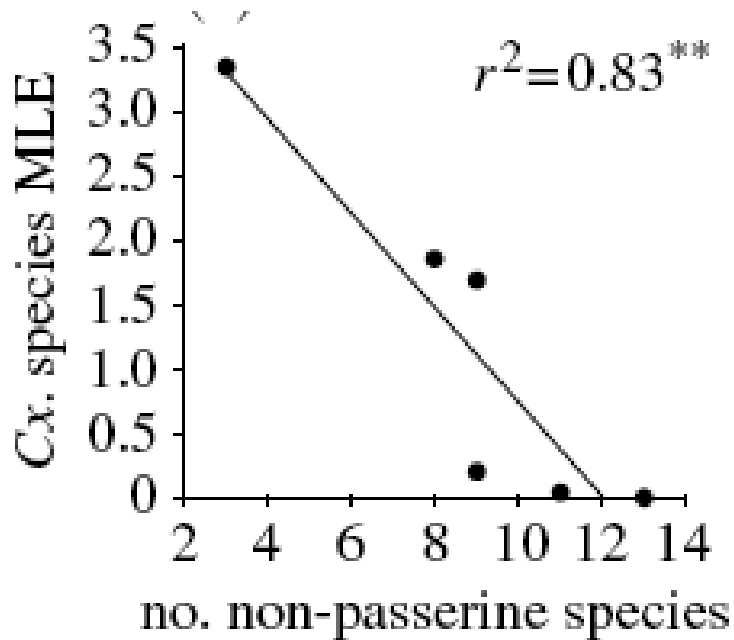


* Modified from Morens et al. 2004 *Nature* 430:242

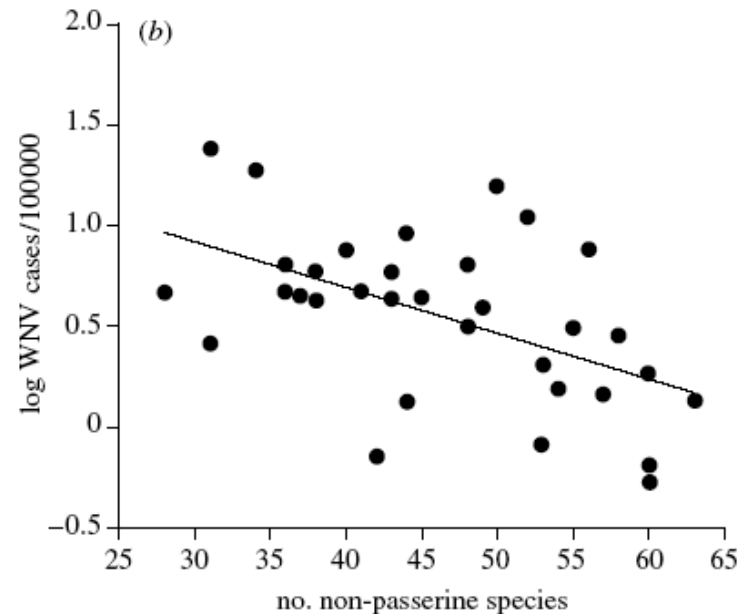
A Modern-Day Epidemiologic Transition?

- First during transition to agriculture (10,000 yr BP)
 - Rise in infectious disease
 - Emerging zoonotics and increased virulence of human pathogens
- Second during Industrial Revolution (19th century)
 - Shift from infectious to chronic diseases
 - Increased water and air pollution linked to higher rates of cancer, allergies, birth defects, and impeded mental development
- Third during period of globalization and ecological collapse
 - Rise of emerging and re-emerging diseases and antibiotic resistance
 - Linked to biodiversity decline?

Increasing biodiversity moderates risk of West Nile virus in Louisiana



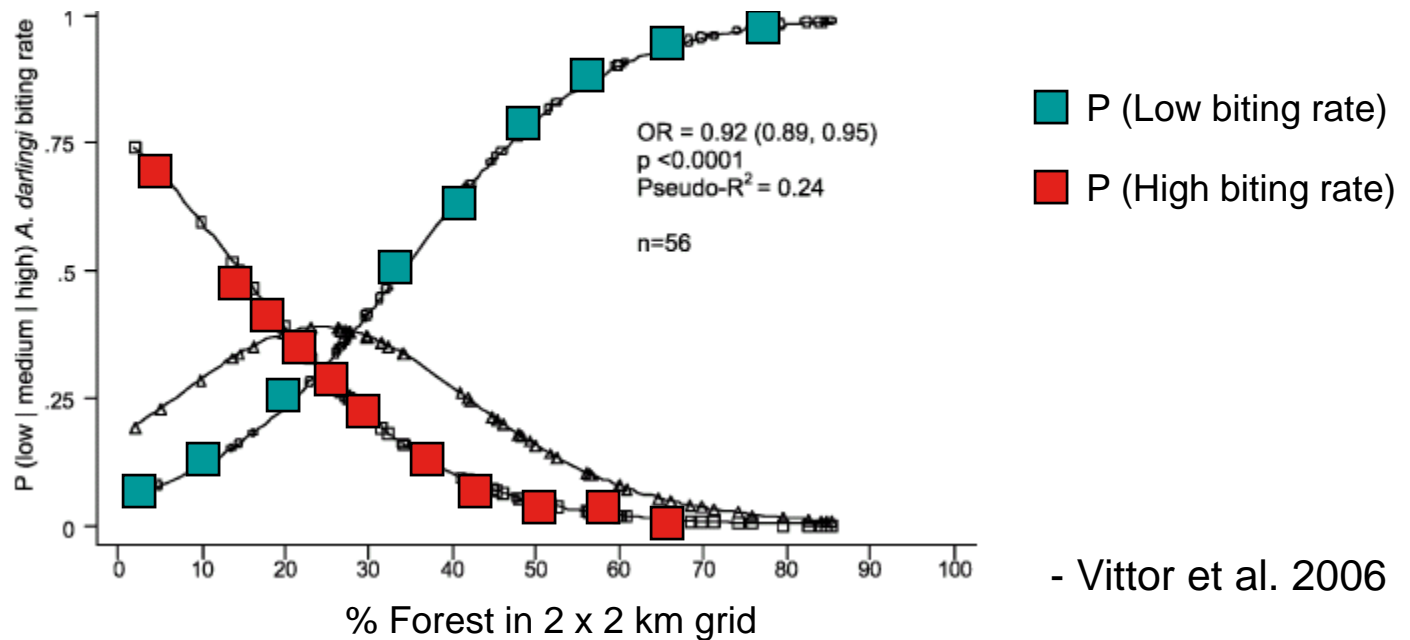
Infection rates of *Culex* mosquitoes declined with increased nonpasserine species richness



Lower infection rates among mosquitoes were correlated with lower numbers of human cases of West Nile virus.

- Ezenwa et al. 2006

Deforestation and Spread of Vector-Borne Diseases



- Vittor et al. 2006

Deforested sites in the Peruvian Amazon had greater mosquito (*A. darlingi*) biting rates compared to sites with less habitat alteration, independent of population density. Landscape features may be useful in predicting mosquito density.

How can changes in biodiversity affect human health?

- Change in host diversity → change in competent host-vector contact rates
- Change in structural diversity → changes in vector abundance and vector-human contact rates
- Change in structural diversity → change in contact rates between hosts and target populations

Interdisciplinary Forum and Workshop on Biodiversity and Human Health September 2006

US EPA, Yale Center for EcoEpidemiology, Smithsonian
Institution, World Conservation Union

- Outreach effort
- Interdisciplinary participation
- Encouraged interdisciplinary collaboration, in the U.S. and internationally
- Workshop discussions on case studies and mechanisms, research priorities, & types of data and models needed to map biodiversity change and emerging diseases



Biodiversity-Health Research Initiative U.S. EPA

- Exploratory research funding – competitive extramural grants and interagency agreements
- Qualitative and quantitative relationships - how do anthropogenic drivers of changes in biodiversity affect the transmission of human infectious disease?
- Interdisciplinary research approach, including managers
- Encourage coordination of earth observation data with field data
- International and domestic projects

Global Earth Observation System of Systems (GEOSS)

- Being developed by the Intergovernmental Group on Earth Observations (GEO) to coordinate environmental monitoring capabilities and systems worldwide to better understand changing environmental conditions.
- Earth observations, both *in situ* and remotely sensed, are integral to understanding biodiversity and its decline over space and time and improving the capacity for analysis and prediction to inform decisionmaking.
- Organized around 9 societal benefit areas



Linking Biodiversity and Health: Research Questions

- What are the mechanisms by which changes in biodiversity affect health?
- At which taxonomic level does biodiversity directly affect health? Are there generalizable patterns across systems?
- What are the ecological (temporal & spatial) scales at which biodiversity affects human health?
- When do we expect ecological risk to be correlated with human disease risk? Or actual health outcomes?
- What are the feedbacks between human behavior, health outcomes, and biodiversity?
- How can global drivers like climate change and migration affect the link between the biodiversity and human health?

EPA-CDC-Yale-NASA Ames: Linking Biodiversity Change to Lyme disease Risk (U.S.)

- Building on an existing CDC-Yale spatial modeling project to test new hypotheses linking tick density and infection rates with new data on meteorology, mammalian, and bird diversity:
 - **Does pathogen prevalence reveal spatial patterns that are dependent on climate and landscape characteristics?**
 - **How does pathogen prevalence respond to changes in habitat structure, vertebrate communities, or other indicators of biodiversity?**
- Use of NASA Terrestrial Observation and Prediction System (TOPS)
- Surface map of human risk for infection from Lyme disease throughout the range of the primary vector, *Ixodes scapularis*
- CDC and EPA are collaborators

Ecology of Lyme disease Risk (New York, U.S.A)

Apr 2008 – Apr 2011

- Characterize the ecological mechanisms underlying Lyme disease (LD) risk
- Manipulate host diversity and community composition by removing and translocating two competent mammalian reservoirs and one incompetent reservoir in forest fragments while monitoring abundances of other hosts.
- What is the effect on tick abundance and infection rates?
- Mechanisms by which high host diversity might reduce disease risk:
 - reducing encounter rates between ticks and the white-footed mouse
 - regulating abundance of the mouse host
 - regulating abundance of the tick
- Interdisciplinary work

The Role of Plant Biodiversity in the Ecology of Hosts, Vectors and Humans (New Jersey, U.S.)

Apr 2008 – Apr 2011

- H(a): Structural diversity is the ultimate driver of host and vector species diversity; and, plant biodiversity can influence human behavior
- Test causal relationships between plant diversity, bird diversity, mosquito diversity and viral prevalence, as well as human perceptions of diversity, values and behavior in adjacent residential communities
- New Jersey urban wetlands
- Data analyses will utilize a variety of components of diversity, in addition to species richness
- Collaborations with a state environmental protection agency and an environmental NGO will enhance the application of results.

EPA-Smithsonian Institution: Monitoring Mosquito Diversity over a Landscape Gradient (Panama)

- Biodiversity decline through deforestation can affect vector density and composition
- Deforestation effects microclimate changes that affect mosquito reproduction, density and survival
- How mosquito populations respond to land use and regional climate change over time can have implications for human risk of disease
- Monitoring across the landscape gradient inside and outside a tropical forest tree plot (Barro Colorado Island, Panama)
 - **How do changes in climate and landscape affect mosquito species density, relative abundance, distribution, and composition?**
 - **Is there a relationship between mosquito species diversity and pathogen diversity?**

Why is this Research Important?

- Root causes of disease emergence and spread should be explored to assist in prevention and mitigation
- Environmental and social factors contribute to these diseases – and environmentally-based and behavioral approaches can help reduce their burden
- Lack of tools and approaches that link biodiversity to human health

Protecting Biodiversity, Protecting Human Health

- Environmental factors contribute to emerging diseases and environmental strategies can reduce their burden
- Development of new tools to monitor and forecast risks
- Information that can be used to value biodiversity conservation related to health
- Improved strategies and communication which can encourage changes in human behavior
- Improved analysis of land use planning that considers environmental and human health impacts
- Better communication and coordination among environmental and health managers to protect both environment and health



Biodiversity and Human Health

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Research Program



The National Center for Environmental Research (NCER) at the U.S. Environmental Protection Agency's (EPA) Office of Research and Development has proposed a joint Ecosystem-Health research program to study the links between changes in biodiversity and risks to human health. The loss of biodiversity is accelerating while infectious diseases appear to be emerging and re-emerging at a faster rate. Research on the links between these two conditions can have an important impact on our view of biodiversity, the services provided by natural ecosystems, and how we manage them. NCER proposes to study how anthropogenic drivers of changes in biodiversity can affect the transmission of disease.

The biodiversity-human health project complements existing domestic and international priorities to assess and manage emerging human diseases and ecosystem health hazards. But the research program is unique in its plans to link earth observation data to the societal benefits outlined in the GEOSS 10-Year Implementation Plan: (1) understanding the environmental factors affecting human health and well-being, and (2) conserving biodiversity (GEOSS 2005).

The initiative on biodiversity and human health is being led by the U.S. EPA in partnership with the National Oceanic and Atmospheric Administration, the Center for Health Applications of Aerospace Related Technologies at NASA Ames Research Center, and the Smithsonian Institution.

<http://www.epa.gov/ncer/biodiversity>
pongsiri.montira@epa.gov

Research Program

Background

Interdisciplinary Forum
and Workshop

Research Solicitation

Partner Programs

Global Statement of
Need

Related Links

Selected Readings

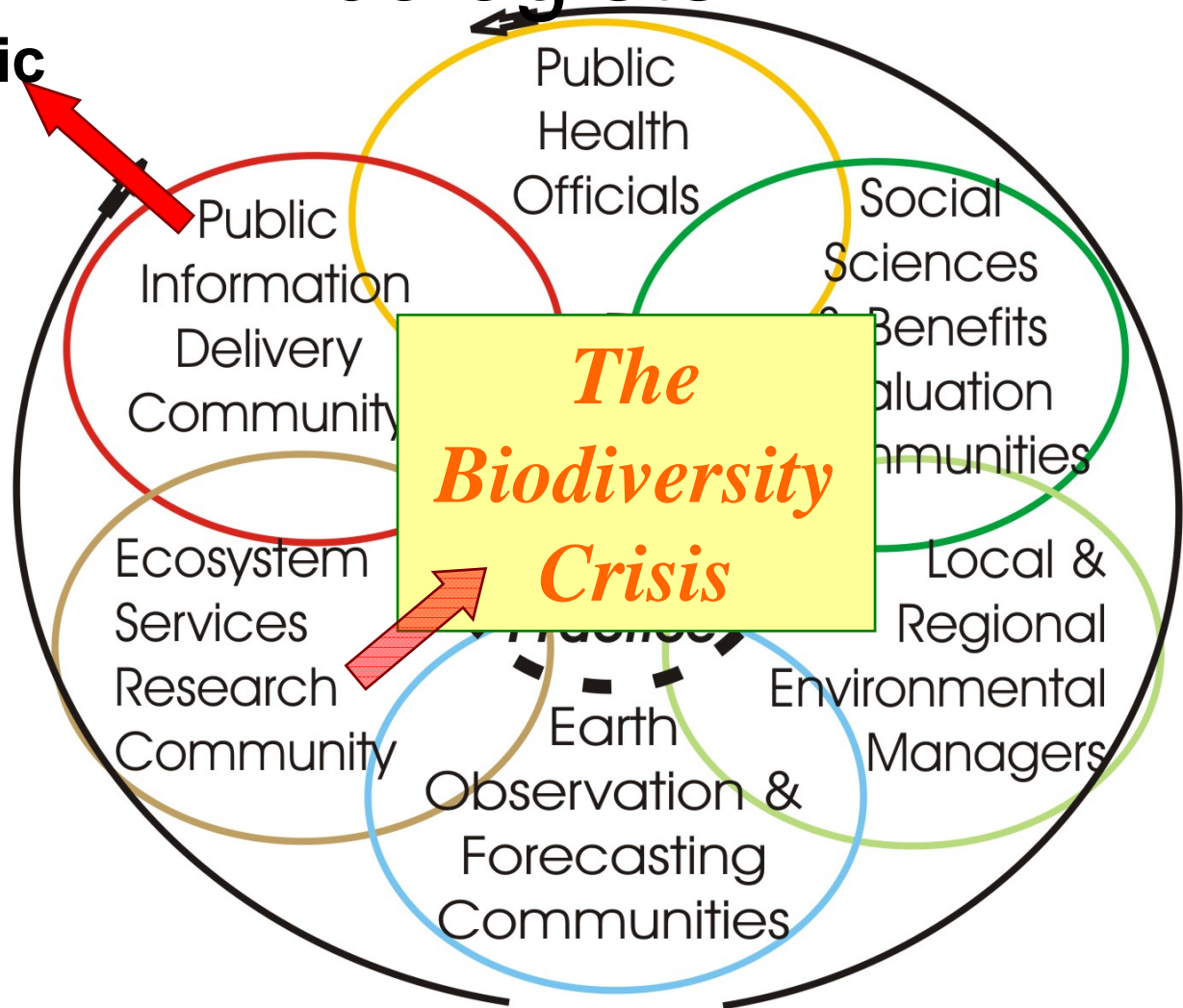
Upcoming Events

Role of Social Stressors and Birds on West Nile virus Transmission (U.S.A.)

- Apr 2008- Apr 2011
- Researchers will examine the spatial and temporal patterns of West Nile Virus (WNV) in 10
- Neotropical passerines and contrast samples from pre- and post-WNV occurrence to determine whether particular species have experienced population declines.
- Based on the prevalence across selected species, they will also determine whether particular taxa are acting as species-equivalents of WNV “superspreaders.”
- Bioclimatic and satellite-based remotely sensed data will be used to determine the environmental correlates of infection.
- Using recently developed distribution models (Maxent), the presence/prevalence of WNV in North America will be mapped, and researchers will examine whether changes in climate have affected distribution.
- Regarding social stressors, investigators plan to identify the possible correlates between geographical WNV hotspots and areas where anthropogenic activity has altered the environment, and contrast models of predicted prevalence with actual incidences of human infections.

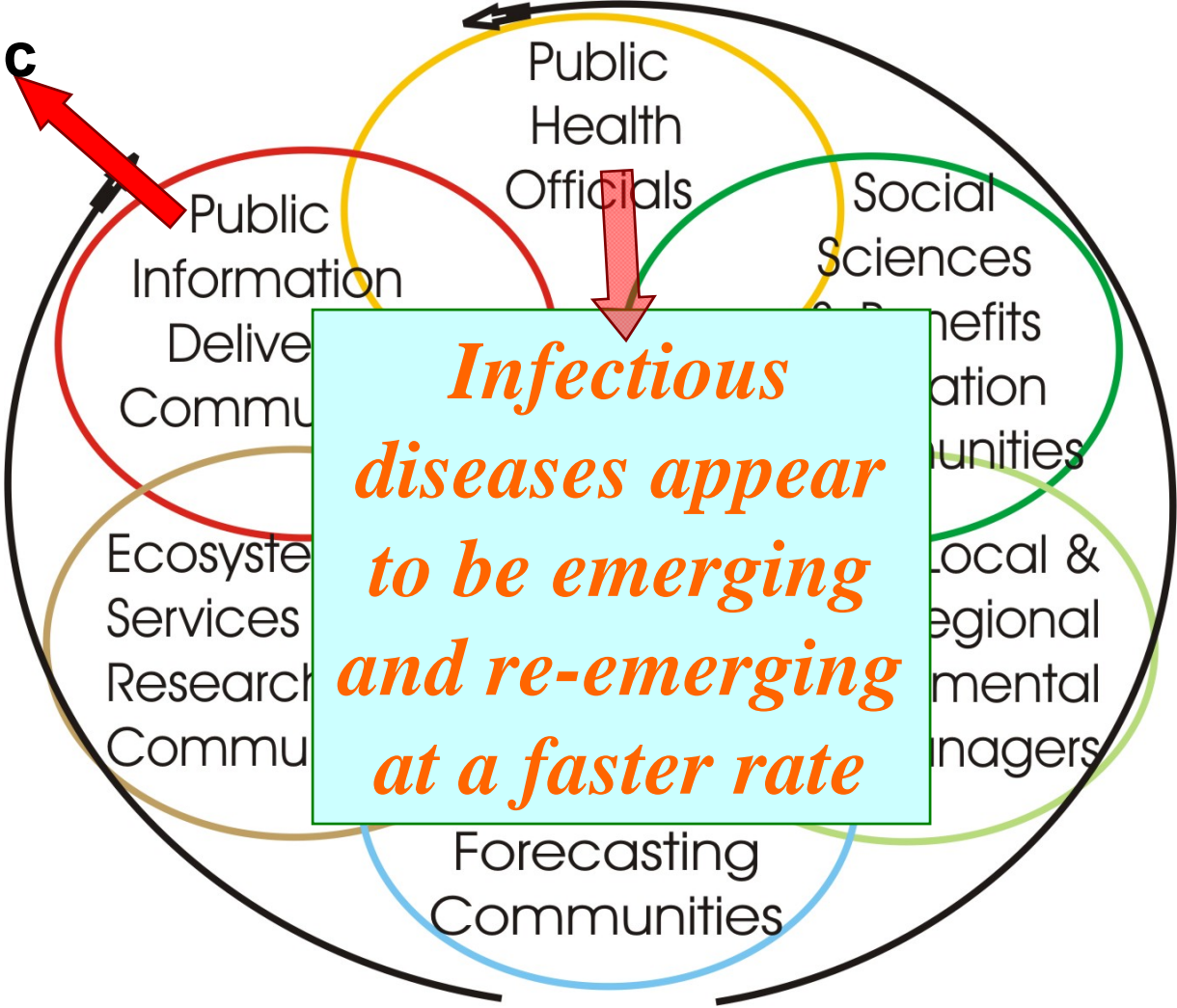
Start with an Issue From the Ecologists

The Public



Look for the Connection with a Public Health Issue

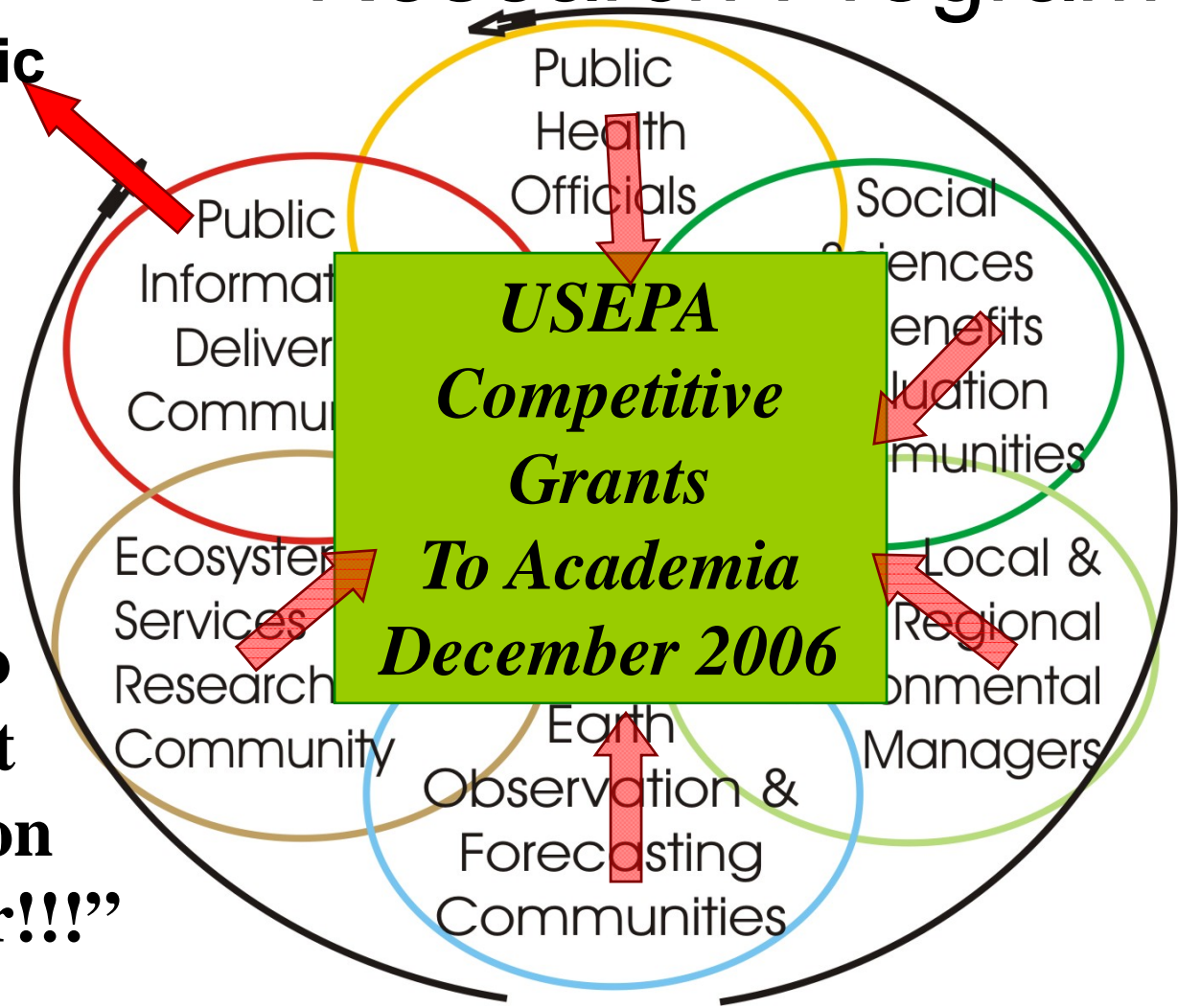
The Public



Infectious diseases appear to be emerging and re-emerging at a faster rate

Launch an Interdisciplinary Research Program

The Public



**“Those who
get better at
collaboration
will prosper!!!”**

GEOSS – applying available
earth observations to study
biodiversity and health

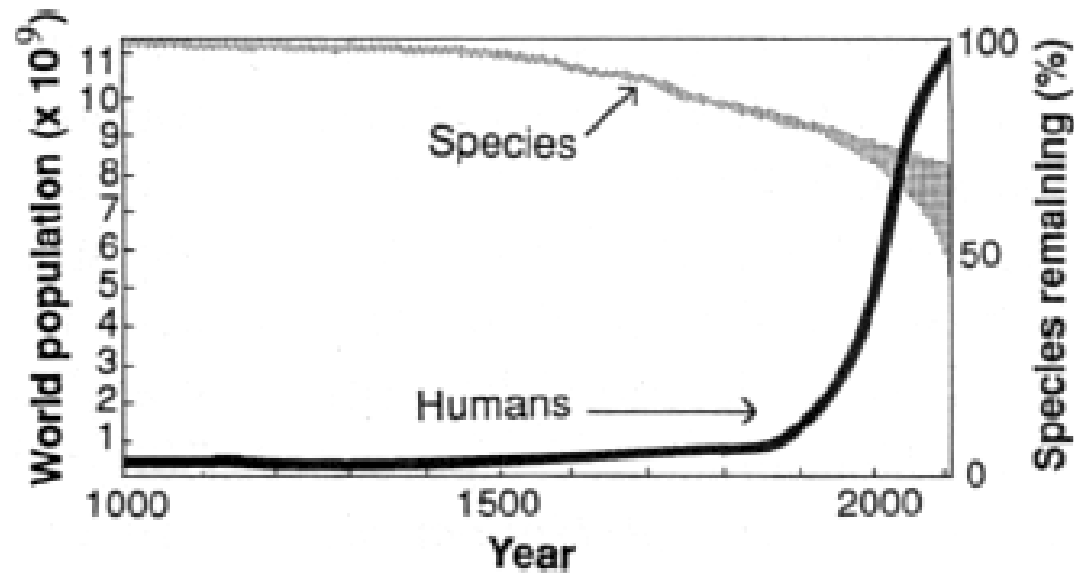
GEOSS Approach and Value-Added

- Pillars of Sustainability
- SBAs
- Links to international activities, and linkages among them

Community of Practice

- Foley figure

The Biodiversity Crisis



Human actions are causing a biodiversity crisis, with species extinctions up to 1000 times higher than background rates

-Pimm et al. 1995

EPA Extramural Research

Anthropogenic Stressors, Biodiversity, and Health

Disease Systems	Multidisciplinary	Location/ Scale	Use of Earth Observations	Research Products	Decision-Making Context
West Nile virus Plague Malaria Dengue St. Louis Encephalitis Hantavirus Pulmonary Syndrome	Ecology Epidemiology Parasitology Climatology Psychology Wildlife Biology Environmental and Health Managers	US – county or state level (East, West, Southwest) Intl – country or regional level (SE Asia, South America, Africa)	Land cover/change Plant biodiversity Habitat Climate	New knowledge characterizing mechanisms that link biodiversity change and disease transmission and emergence Risk models of disease emergence	Inform land use planning and development Inform disease control and management with minimal harm to the environment Inform how to protect landscape diversity for ecosystem services that benefit health Inform targeting of social and environmental interventions to protect biodiversity and health

Studies propose to look at how changes in diversity of vector and/or host species affect human disease risk, and how changes in diversity are influenced by anthropogenic stressors like climate change, land use change, deforestation

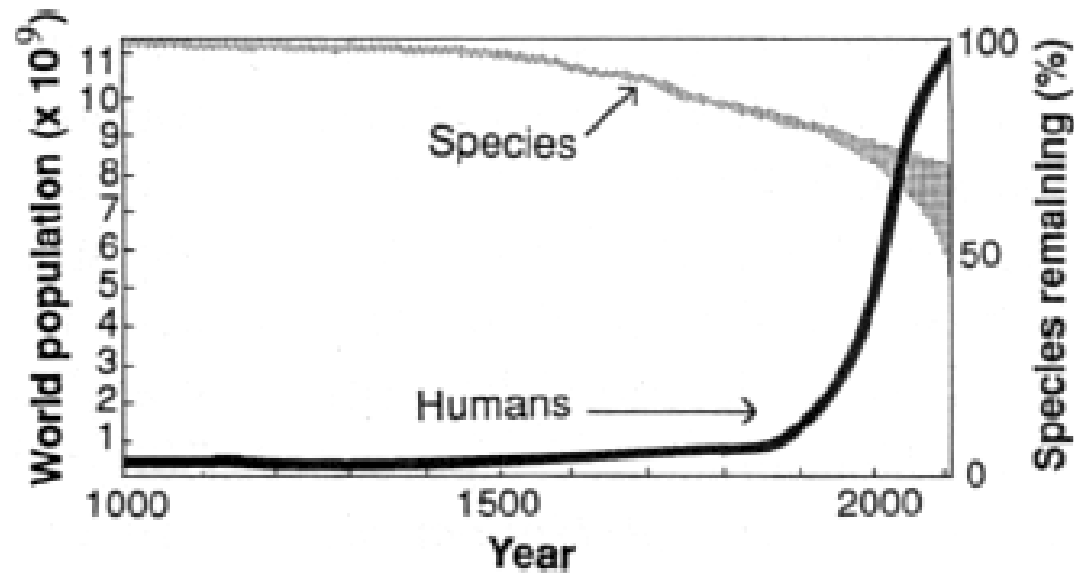
*Awardees to be announced in Fall 2007 after independent peer review

A Possible Biodiversity & Health Community of Practice

The Public
& Public
Officials



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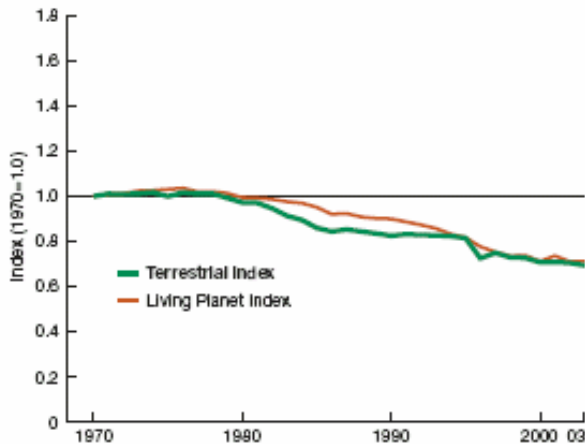


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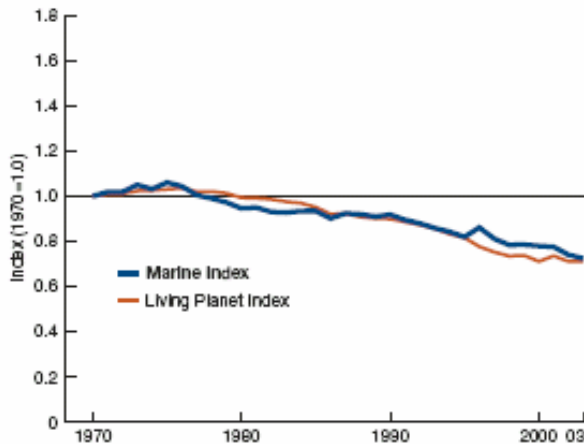
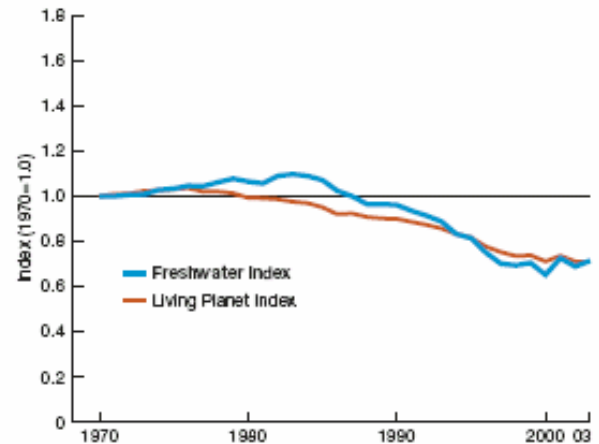


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From WWF, "Living Planet Report," 2006.

BBC NEWS
 Tuesday, 21 May, 2002, 13:48 GMT 14:48 UK
 Front Page World UK
 UK Politics Business
Sci/Tech
 Health Education Entertainment Talking Point In Depth AudioVideo
WORLD CUP
OLYMPIC SPORT
OLYMPIC WEATHER
 SERVICES: Daily E-mail News Ticker

Quarter of mammals 'face extinction'



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THE GREEN CENTURY

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Organ Pipe Cactus National

(CNN) – The complex web of life on Earth, what scientists call "biodiversity," is in serious trouble.

CNN.com / SCIENCE & SPACE
NEXT@CNN

AIRS: Saturdays 3 p.m. ET / Sundays 5 p.m. ET

Study: Only 10 percent of big ocean fish remain

By Marsha Walton
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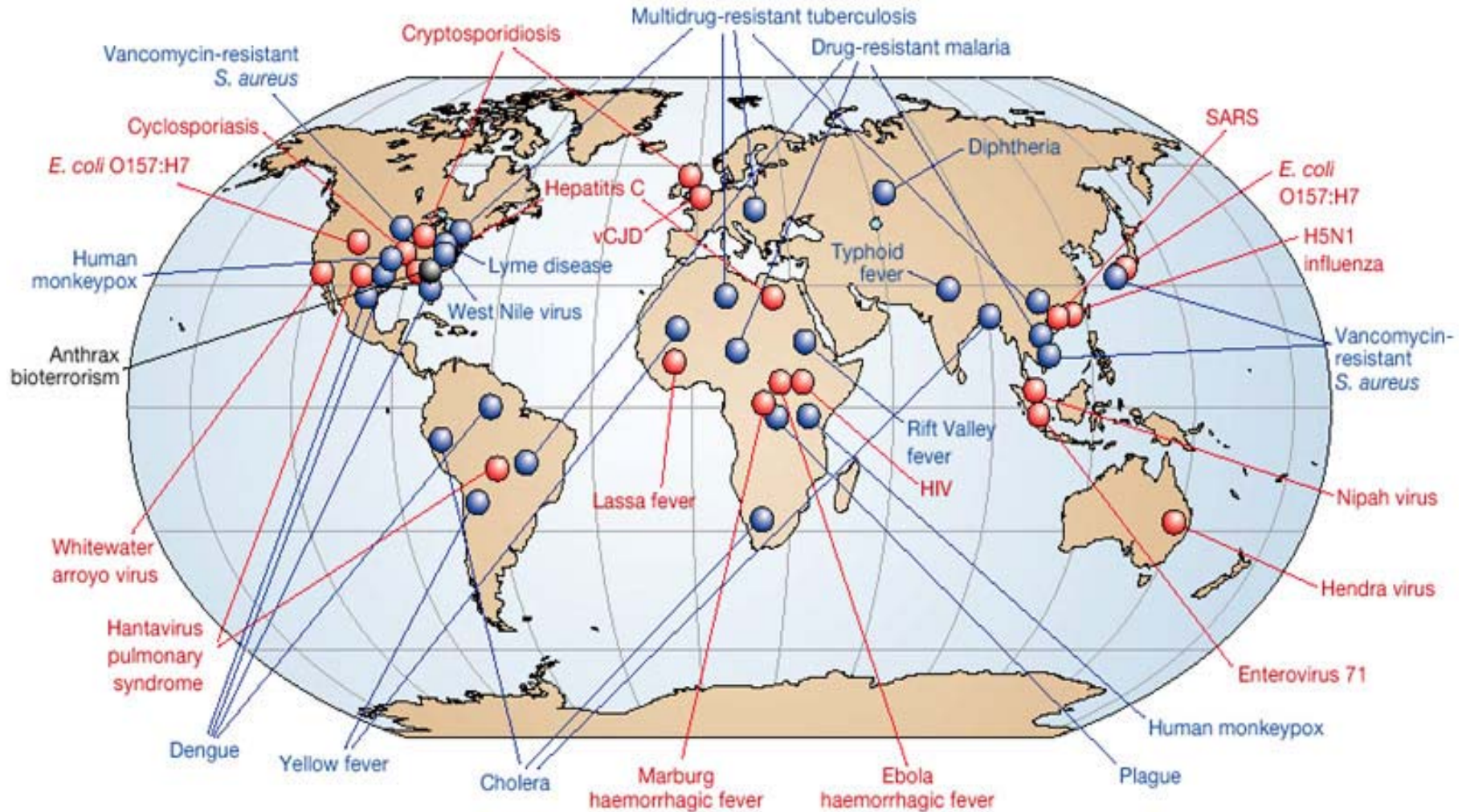


Live with them or lose them

SEE ALSO:
 Wildlife watchers stay away from Kenya
 22 Sep 98 | Africa
 Kenyan lions killed in revenge attacks
 23 Jun 03 | Africa
 Malawi's killer lion shot dead
 24 Feb 03 | Africa

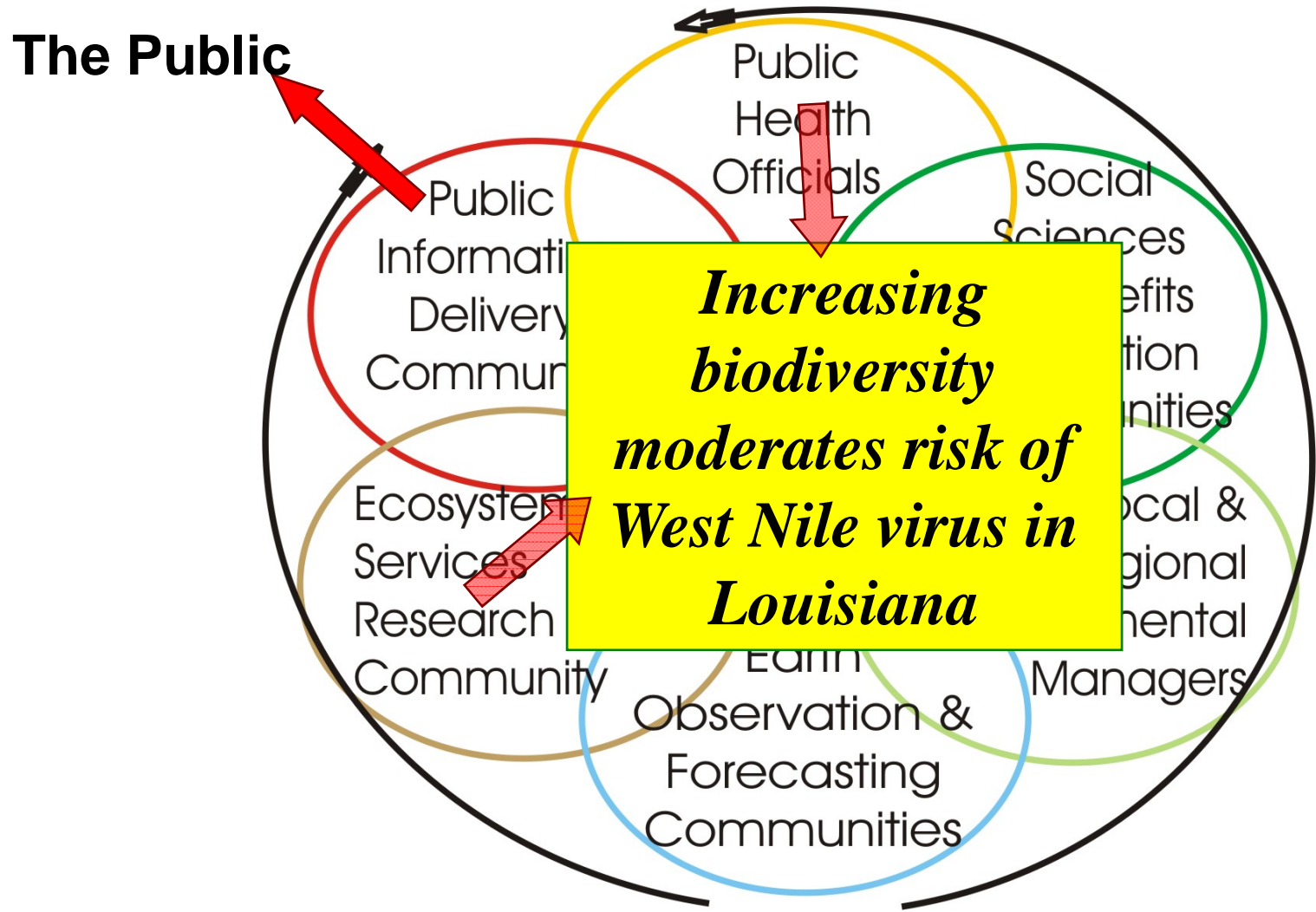
RELATED INTERNET LINKS:

Infectious diseases appear to be emerging and re-emerging at a faster rate

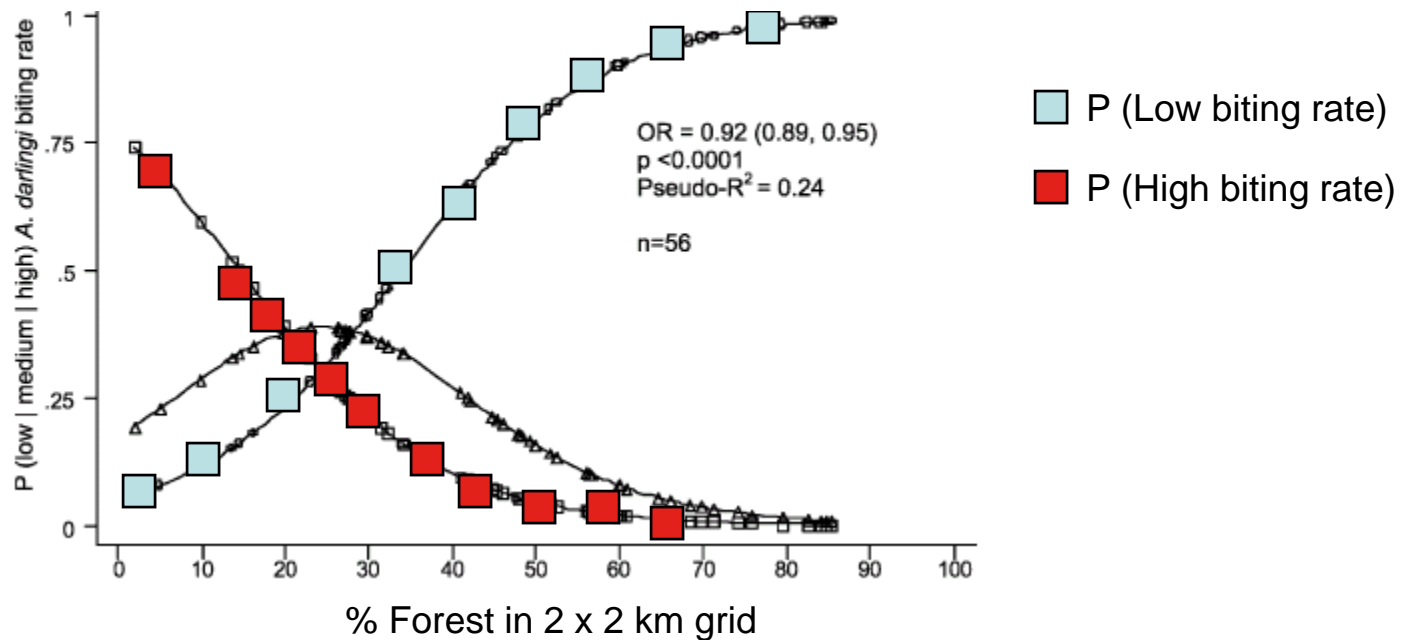


* Modified from Morens et al. 2004 *Nature* 430:242

Explore the Scientific Links



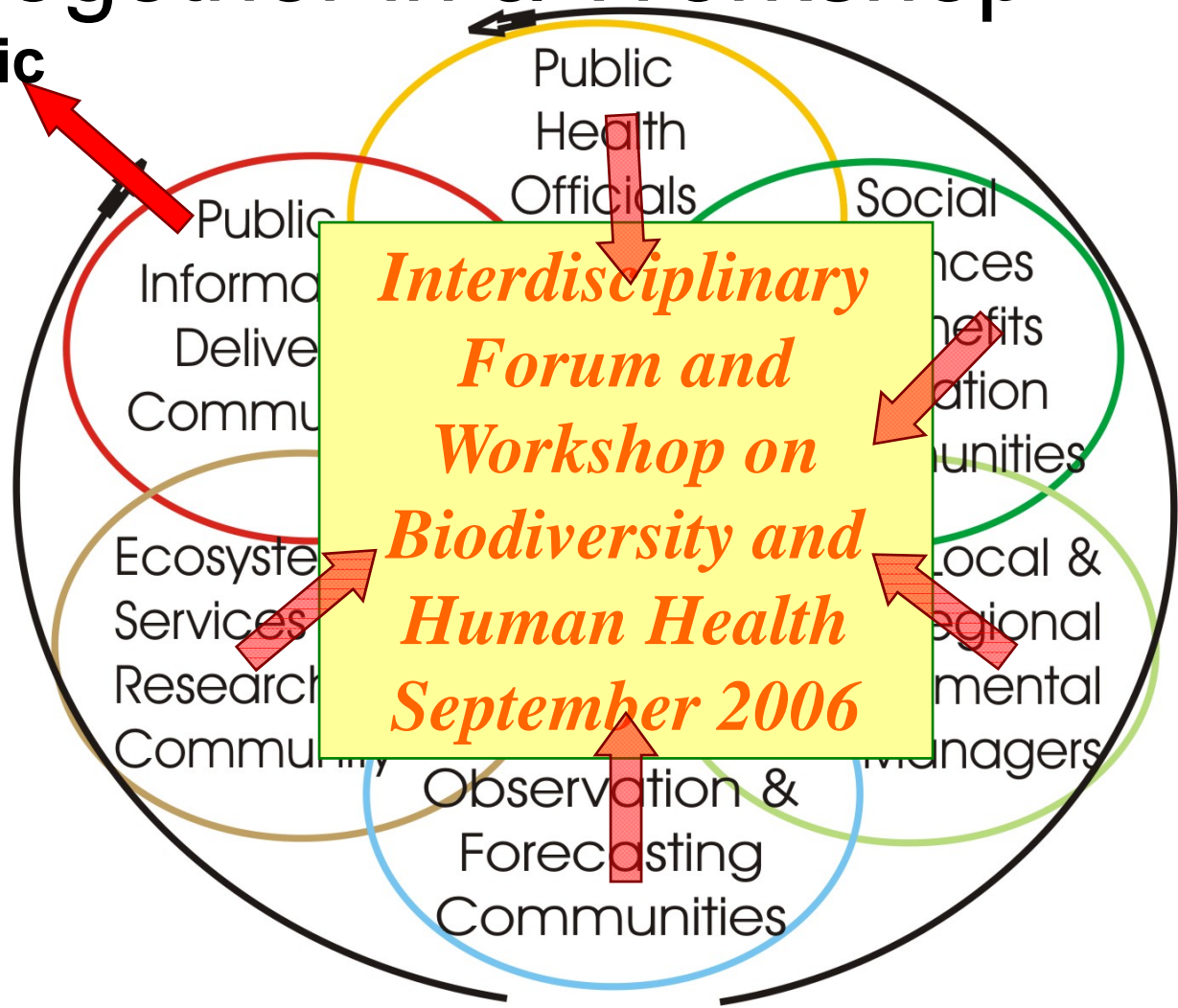
Deforestation and Spread of Vector-Borne Diseases



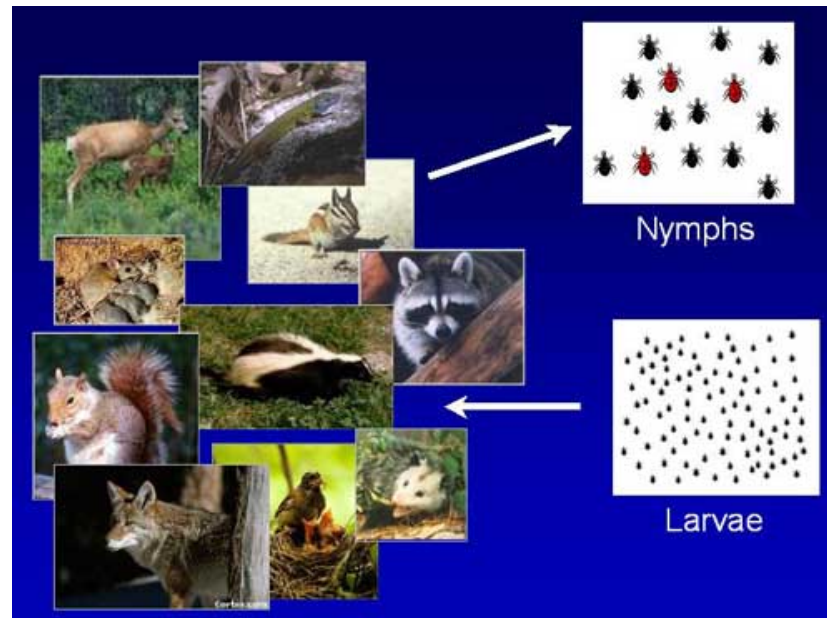
Deforested sites in the Peruvian Amazon had greater mosquito (*A. darlingi*) biting rates compared to sites with less habitat alteration.

Bring Different Communities Together in a Workshop

The Public

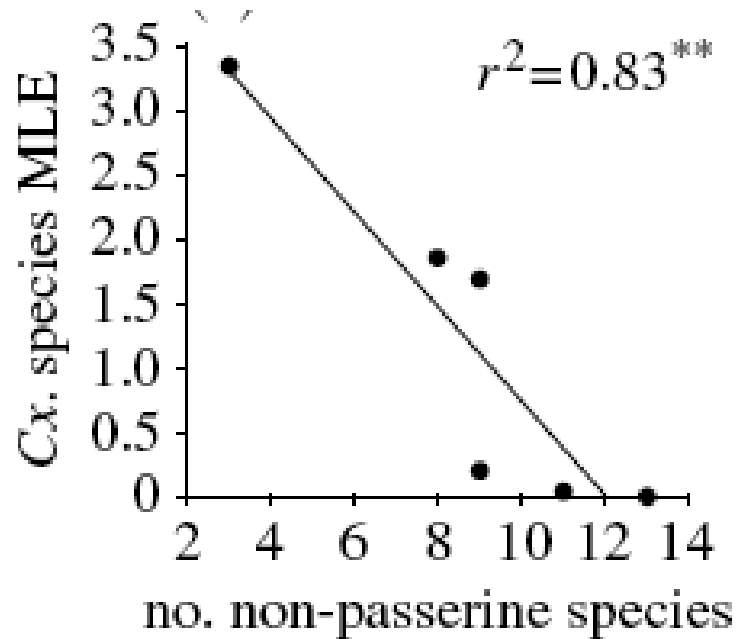


Conditions for a dilution effect



- Generalist vector
- Variation in reservoir competence among hosts
- Positive correlation between reservoir competence and percentage of tick meals supplied by hosts in the community

Increasing biodiversity moderates risk of West Nile virus in Louisiana

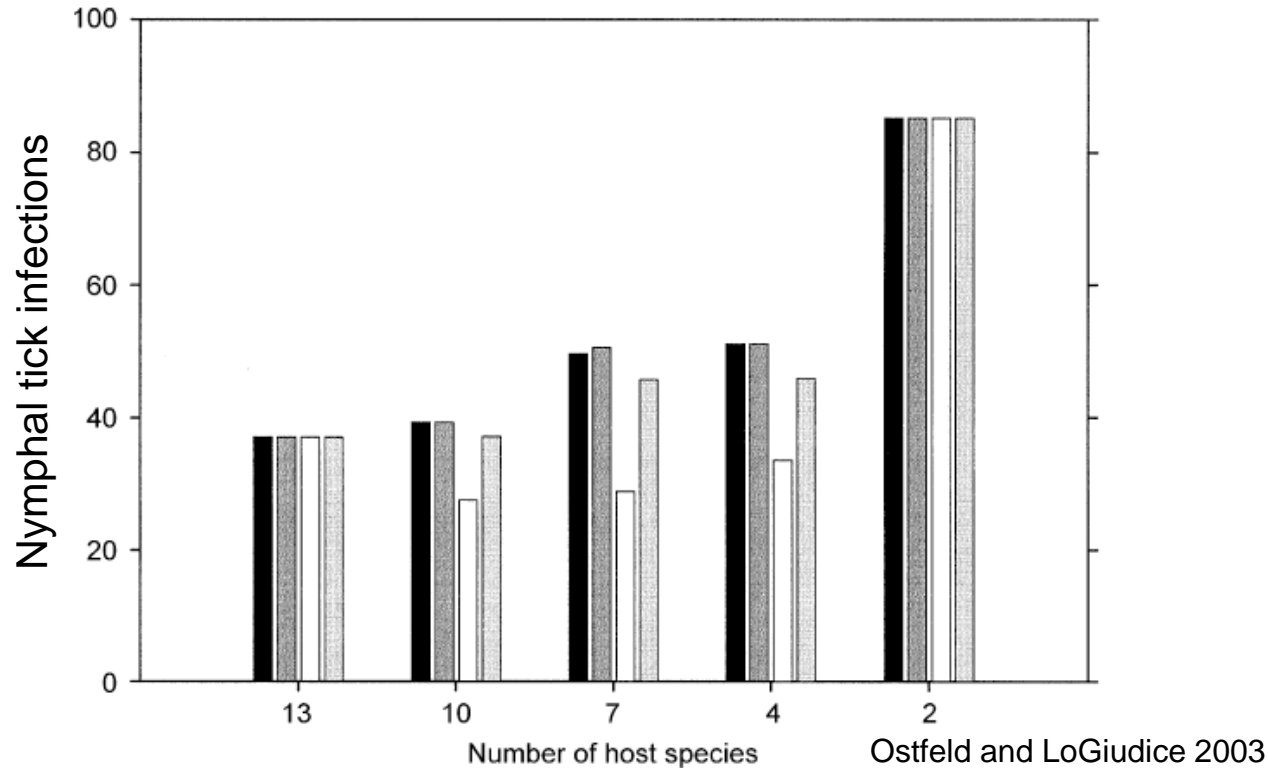


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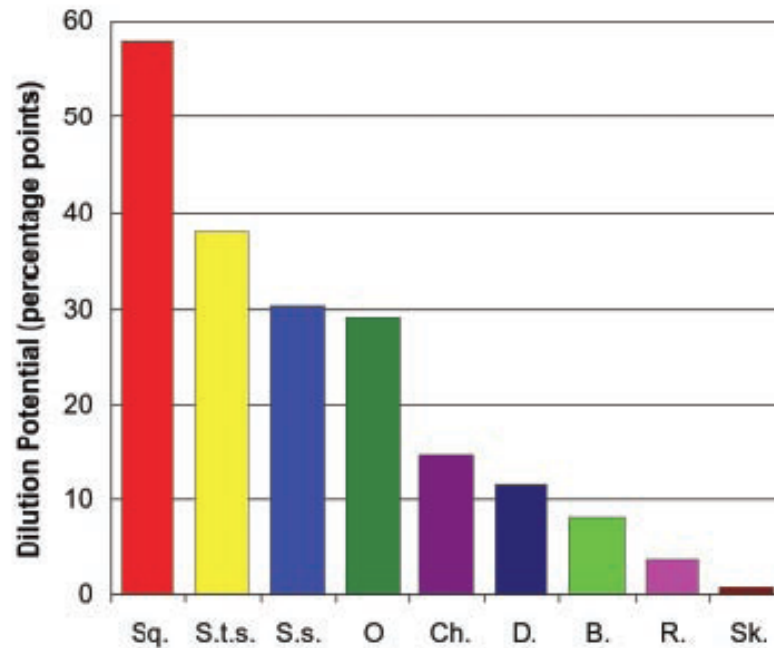
Lower infection rates among mosquitoes were correlated with lower numbers of human cases of West Nile virus.

- Ezenwa et al. 2006

Biodiversity and Lyme disease



Reduced reservoir biodiversity correlates with increased risk of Lyme disease transmission to humans and may be a general rule of frequency-dependent transmission



LoGuidice et al. 2003

Mammalian species from squirrels (Sq) to skunks (Sk) can reduce the effect of white-footed mice, the most competent reservoir of Lyme disease, on tick infection.

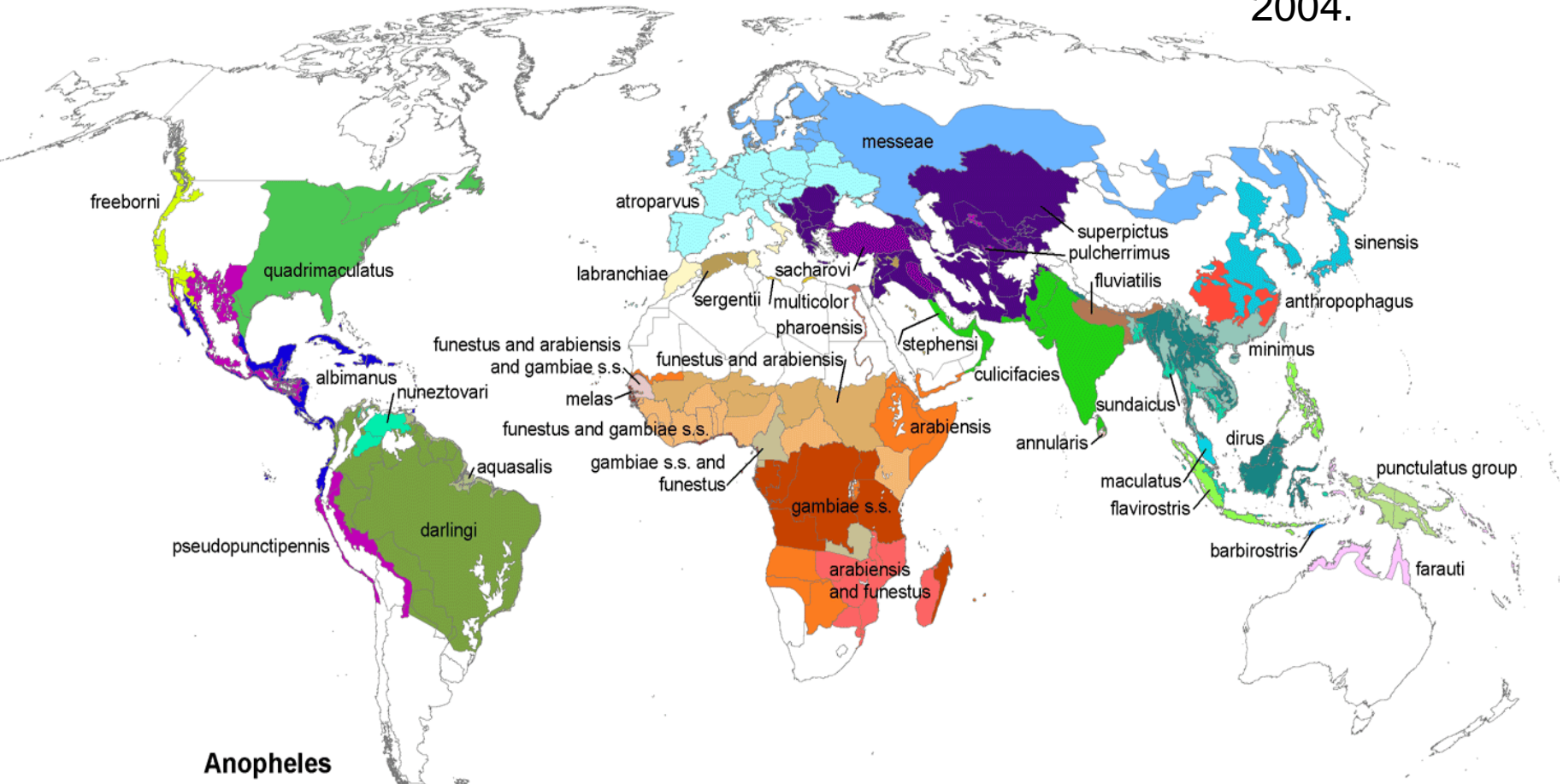
90% of ticks feeding on white-footed mice become infected with Lyme bacterium

Only 15% of ticks feeding on squirrels become infected with Lyme bacterium

Species richness may be only part of the problem, abundance also

Global distribution of dominant or potentially important malaria vectors.

Kiszewski et al.,
2004.



Malaria-transmitting mosquitoes are closely associated with forest communities in SE Asia and active in forest-fringed areas in Central Africa. In the Amazon, closed-canopy forests have no known malaria vectors, and open forests tend to have a lower density and diversity of

Methods

- **Where?** Across landscape gradient, including one site of maximal forest cover: four 1-hectare sites per gradient
- **What to measure?**
 - Adult mosquito richness and abundance, species id (taxonomic and molecular)
 - Screen blood for pathogens using molecular markers
 - Environmental conditions: temperature, breeding site availability
- **How? Collecting Adults:**
 - Set multiple types of traps (CDC light-traps, mosquito magnet traps, gravid traps) per site over 7 consecutive days and nights
 - numbers caught can vary greatly by method
 - Survey twice during rainy and dry seasons

Methods

- **Where?** Across landscape gradient, including one site of maximal forest cover: four 1-hectare sites per gradient
- **What to measure?**
 - Productivity of natural mosquito habitat = number of emerging adult mosquitoes/m²/wk
 - Adult species id (taxonomic and molecular), richness and abundance
 - Environmental factors related to productivity: water temperature, presence of predator species and potential competitors, presence of emergent plants and algae, type of vegetation surrounding breeding site (forest, farm), daily rainfall (Munga et al. 2006; Patz et al. 2004)
- **How?**
 - Within each site of each gradient, use emergence traps in randomly selected habitats to collect mosquitoes for 7