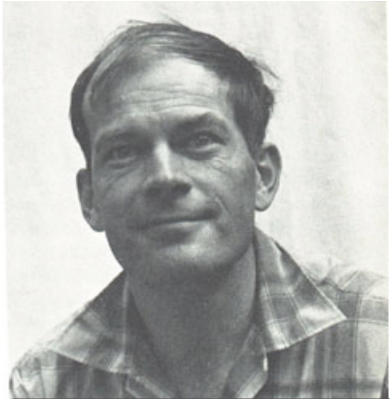
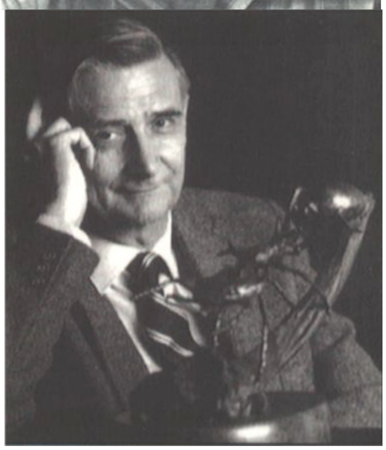
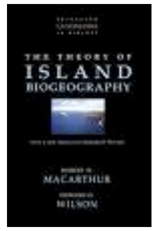
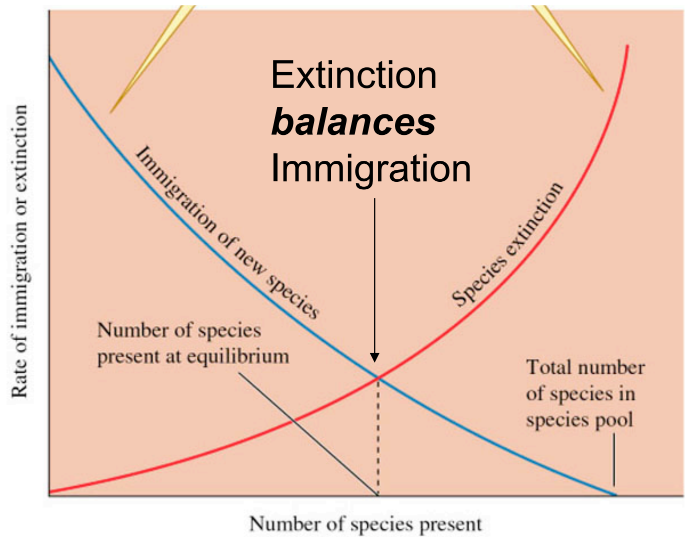




Robert MacArthur and Edward O. Wilson



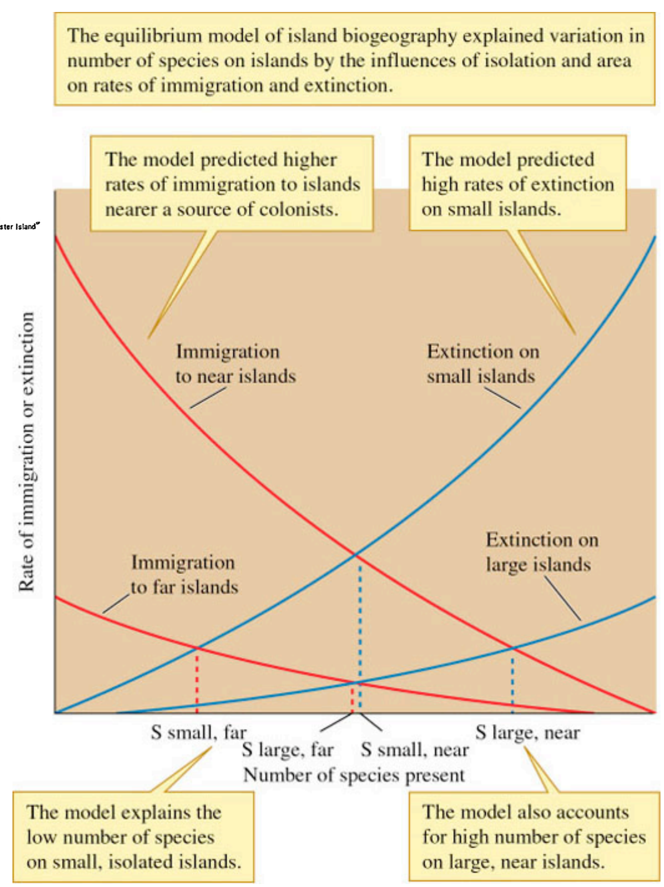
The Theory of Island Biogeography



Assumptions:

Increasing isolation decreases immigration rate

Increasing size decreases extinction rate



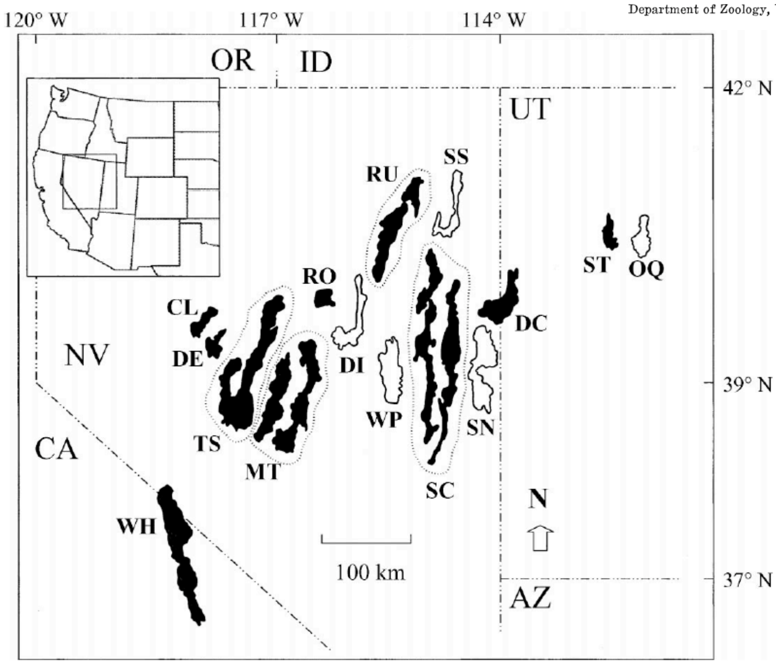
Vol. 105, No. 945 The American Naturalist September–October 1971

Mountaintops as Islands

MAMMALS ON MOUNTAINTOPS: NONEQUILIBRIUM INSULAR BIOGEOGRAPHY

JAMES H. BROWN*

Department of Zoology, University of California, Los Angeles, California 90024

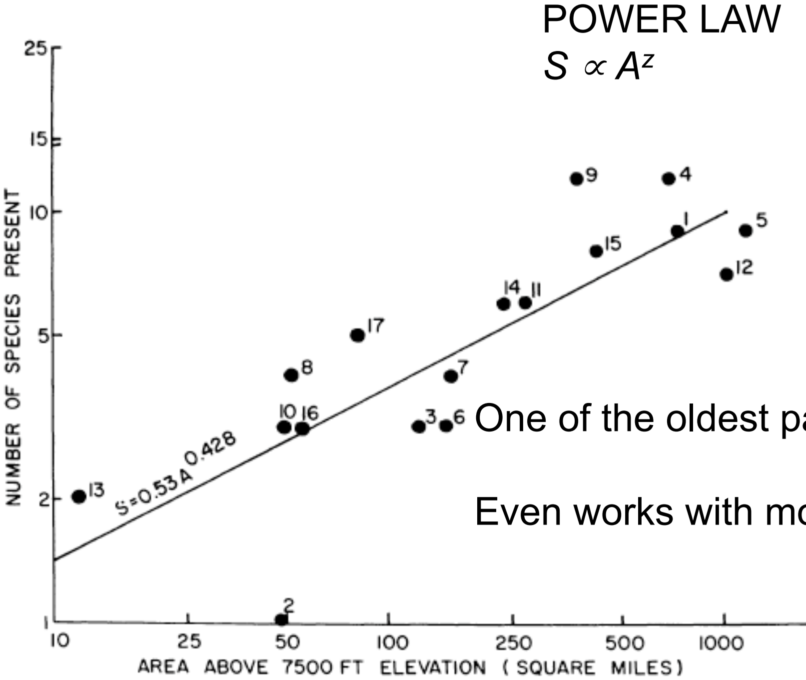


The Species-Area Relationship

Larger "Islands" contain more species

POWER LAW

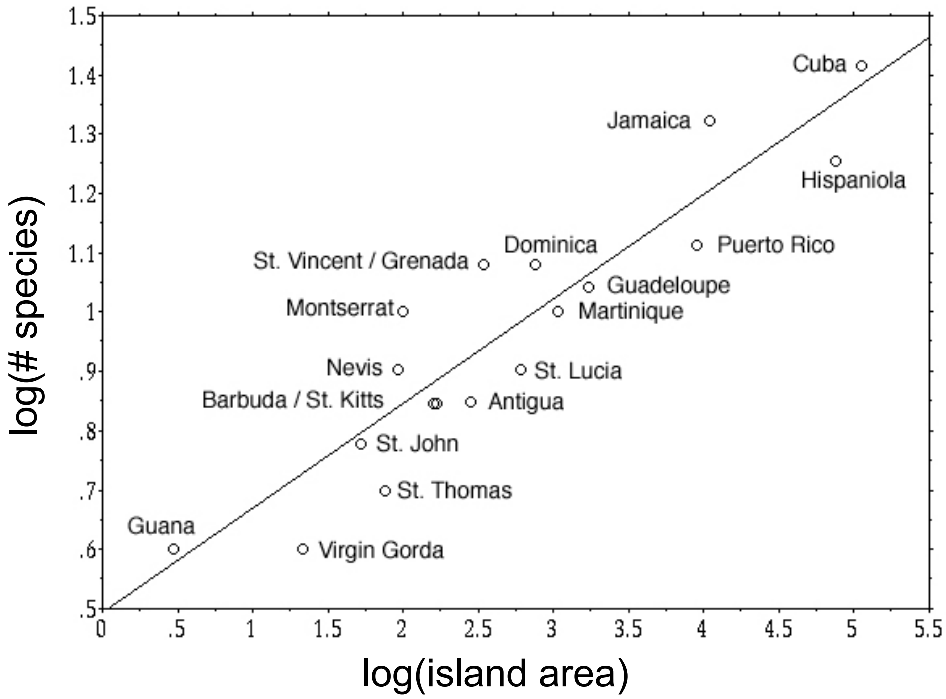
$S \propto A^z$

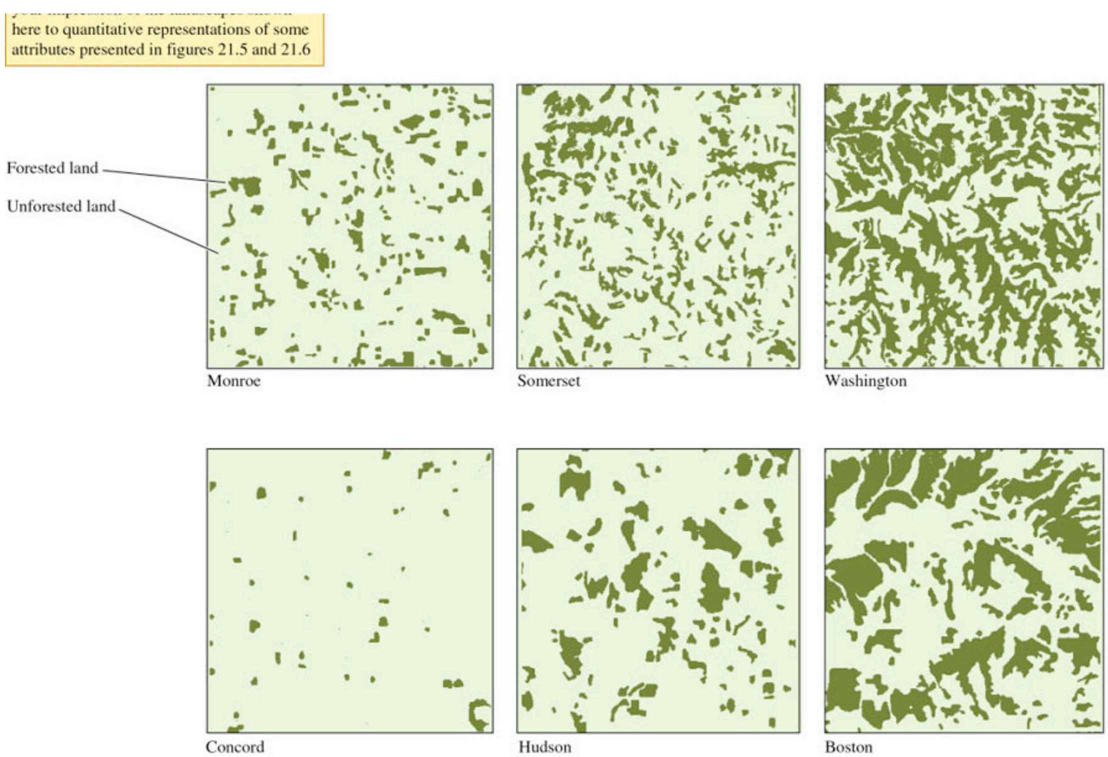


One of the oldest patterns in ecology

Even works with mountaintops

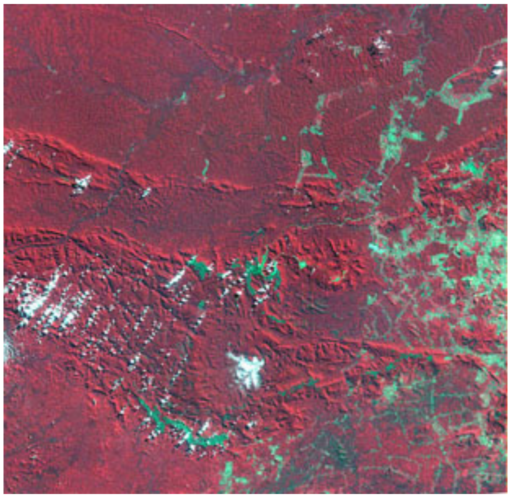
Works on real islands too! - Caribbean Bats



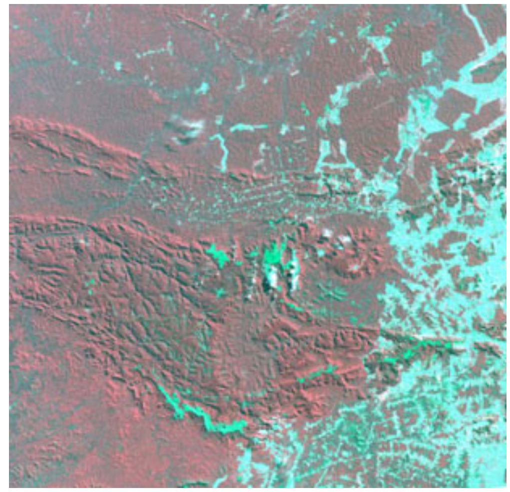


Forested landscapes in Ohio - Shrinking Islands?

Carajas, Brazil

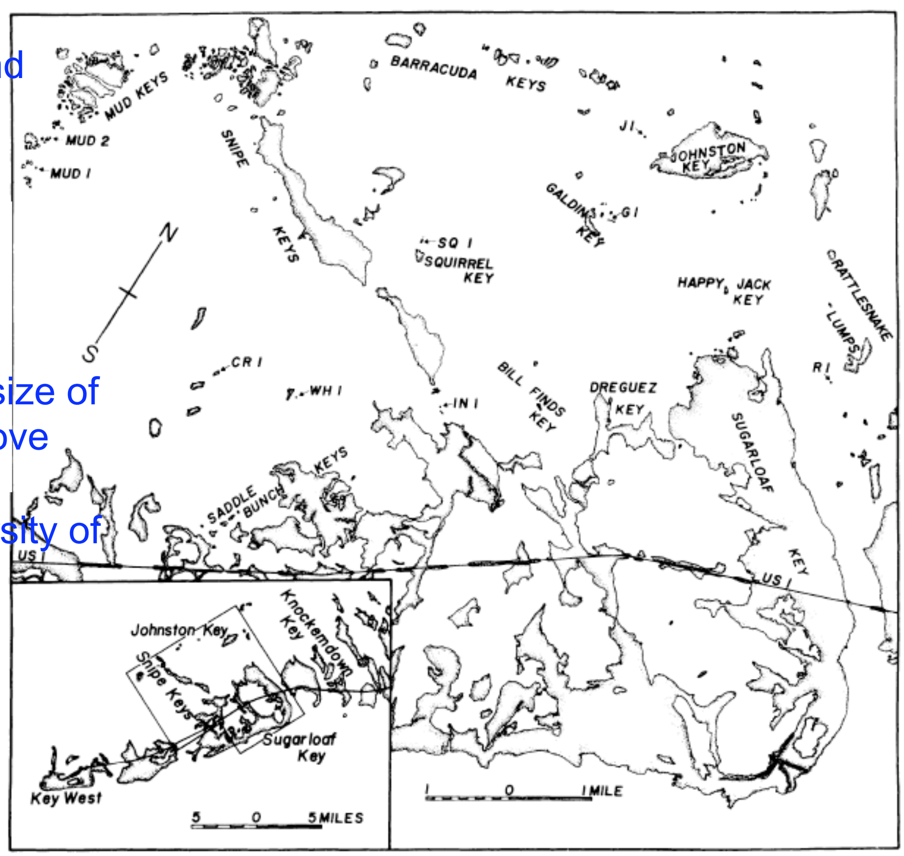


1986

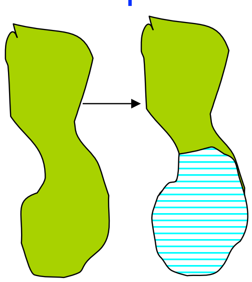


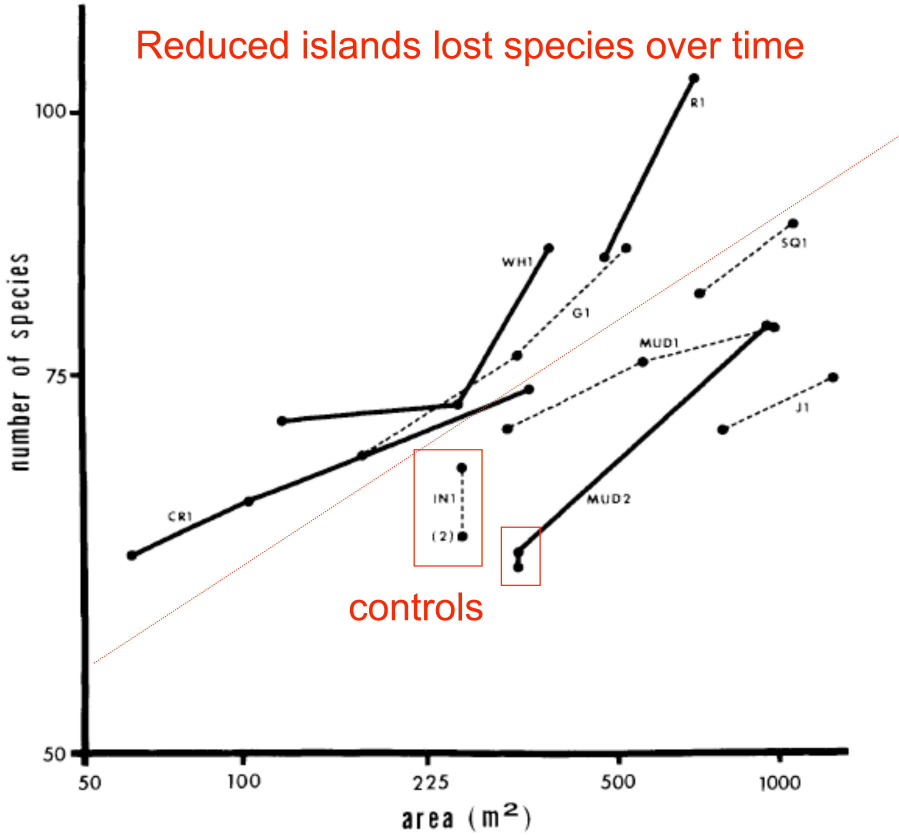
1992

Simberloff and Wilson
Florida Keys
1970s



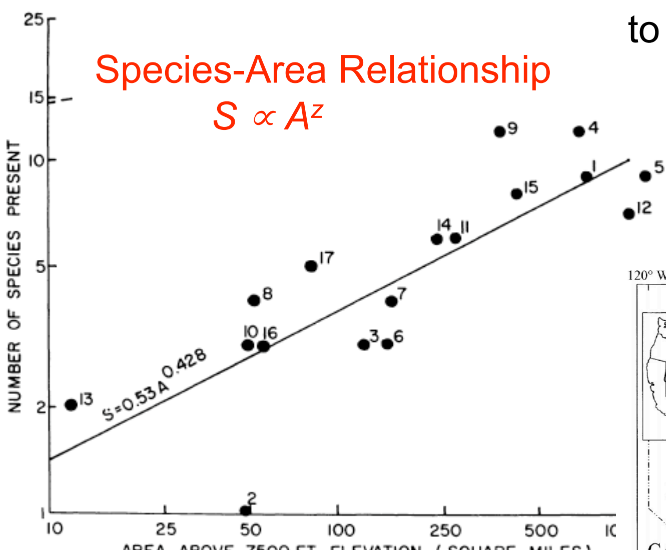
Experiment:
Change the size of small mangrove islands
Monitor diversity of arthropods



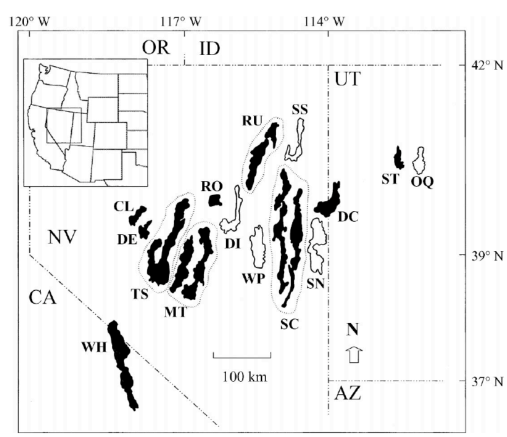


Back to the Mountains

How will the fauna respond to climate change?



THEY ALREADY HAVE!
(since the Pleistocene)



Vegetation zones change with elevation due to climate

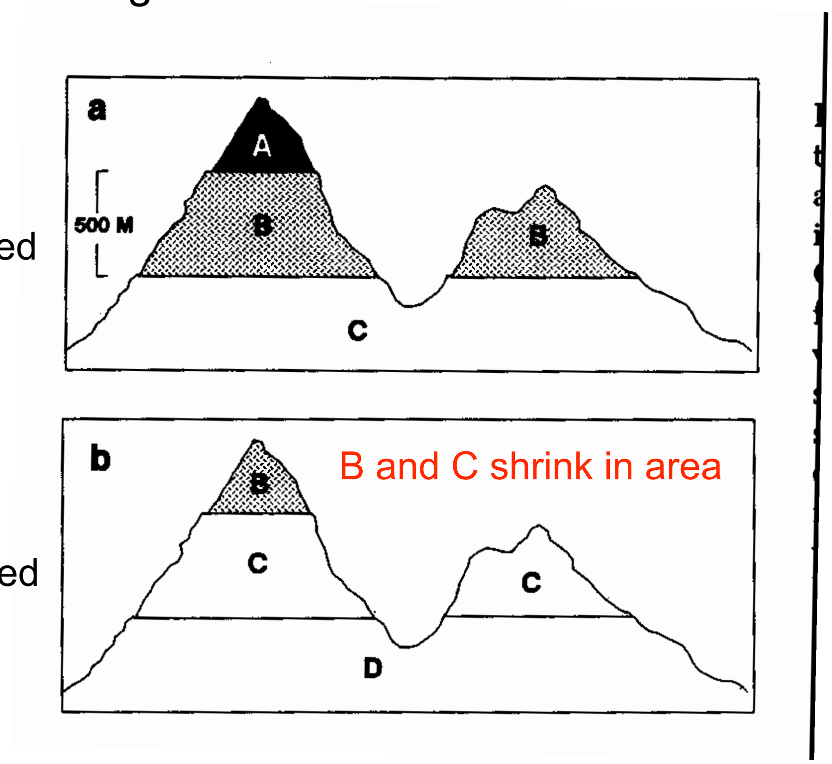
Cooler

- A - rare
- B - patchy
- C - connected

Warmer

- B - rare
- C - patchy
- (new) D - connected

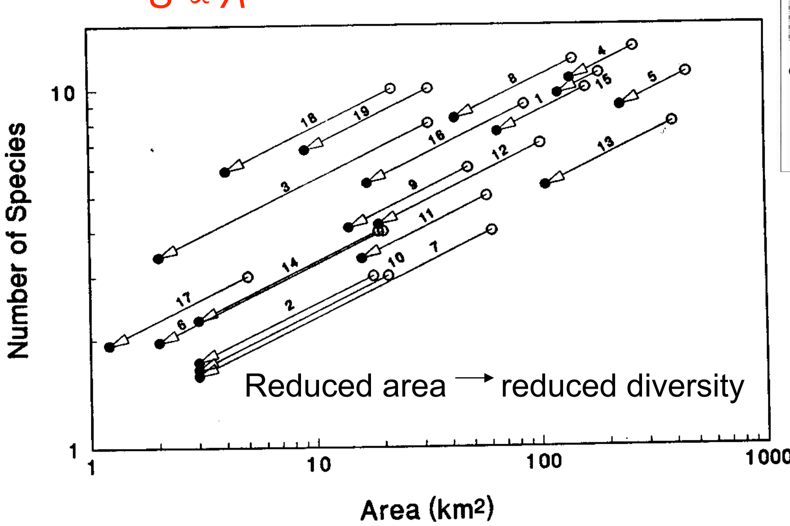
Where's A?

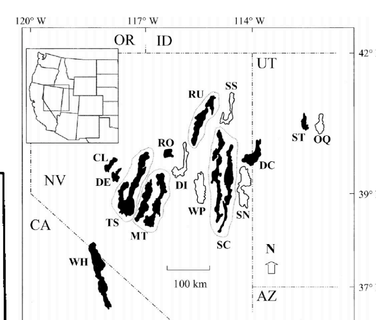


Predicting Responses to Climate Change

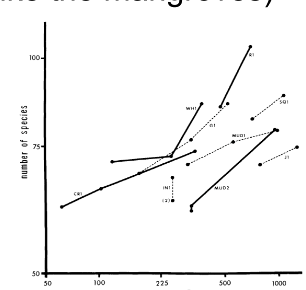
Hypothesis: Diversity of mountain islands will shift along Species-Area Relationship

$S \propto A^z$





(like the mangroves)



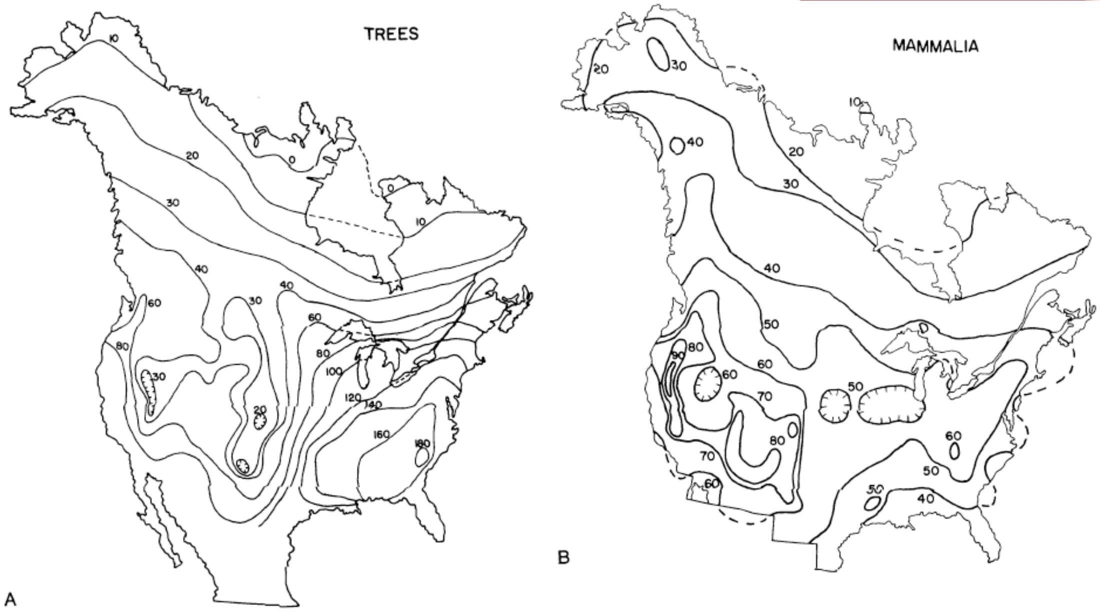
Vol. 137, No. 1 The American Naturalist January 1991

Diversity gradients and climate

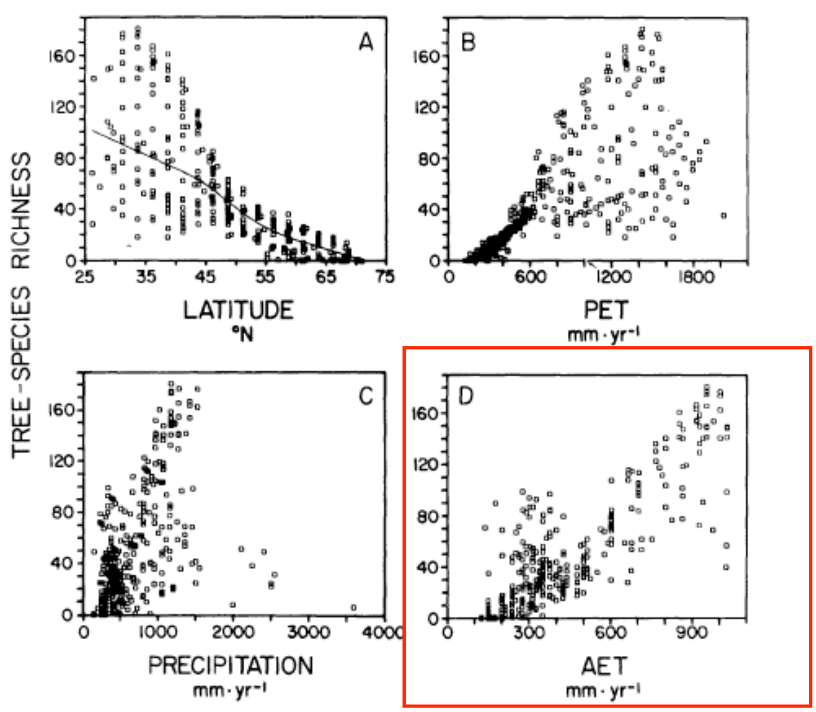
ENERGY AND LARGE-SCALE PATTERNS OF ANIMAL- AND PLANT-SPECIES RICHNESS

David J. Currie
Ottawa-Carleton Institute of Biology, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada

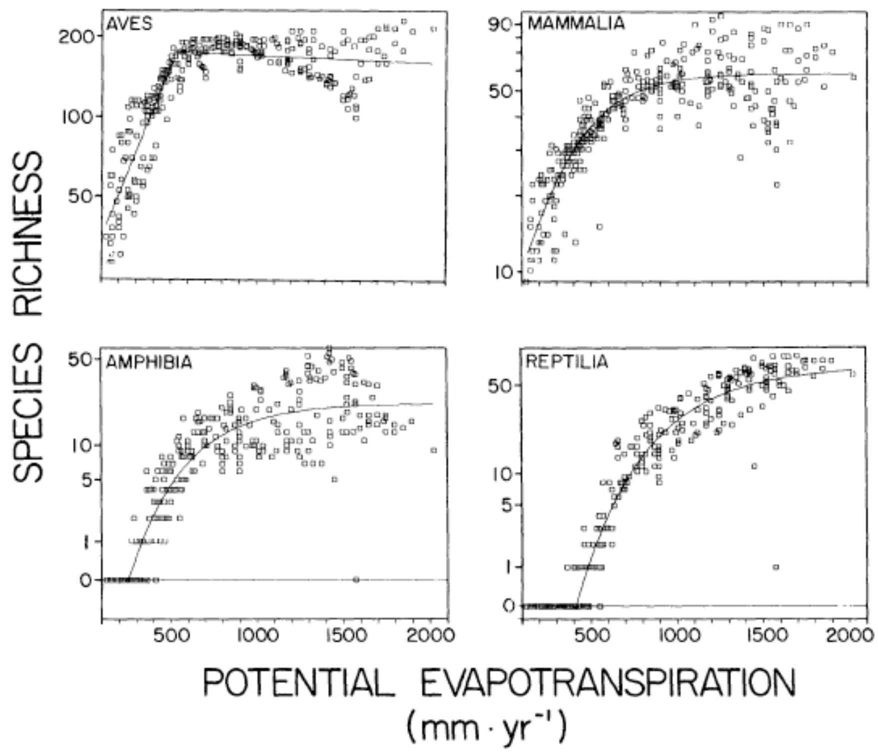
Submitted January 5, 1989; Revised July 6, 1989; Accepted September 30, 1989



Currie 1991



Currie 1991



The value of the world's ecosystem services and natural capital

Robert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farber||, Monica Grasso†, Bruce Hannon¶, Karin Limburg#☆, Shahid Naeem, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Sutton|||| & Marjan van den Belt¶¶**

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Table 1 Ecosystem services and functions used in this study

Number	Ecosystem service*	Ecosystem functions	Examples	$\$ \times 10^9\ ha^{-1}\ yr^{-1}$
1	Gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.	1,341
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.	684
3	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.	1,779
4	Water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.	1,115
5	Water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.	1,692
6	Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.	576
7	Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.	53
8	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.	17,075
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.	2,277
10	Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.	117
11	Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.	417
12	Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.	124
13	Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.	1,386
14	Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.	721
15	Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).	79
16	Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.	815
17	Cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.	3,015

* We include ecosystem 'goods' along with ecosystem services.

The value of the world's ecosystem services and natural capital

Robert Costanza[*†], Ralph d'Arge[‡], Rudolf de Groot[§], Stephen Farber[‖], Monica Grasso[†], Bruce Hannon[¶], Karin Limburg[#☆], Shahid Naeem[**], Robert V. O'Neill[††], Jose Paruelo[‡‡], Robert G. Raskin[§§], Paul Sutton[‖‖] & Marjan van den Belt[¶¶]

Ecosystem services ~\$33 trillion (10^{12})
Global GNP ~\$18 trillion (10^{12})

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US\$16–54 trillion (10^{12}) per year, with an average of US\$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US\$18 trillion per year.

Estimated value of ecosystem services is of the same **same magnitude as GLOBAL gross national product.**

This was 1997…
Cost of the recent financial crisis was ~\$5 trillion

The value of the world's ecosystem services and natural capital

Robert Costanza[*†], Ralph d'Arge[‡], Rudolf de Groot[§], Stephen Farber[||], Monica Grasso[†], Bruce Hannon[¶], Karin Limburg[#☆], Shahid Naeem[**], Robert V. O'Neill[††], Jose Paruelo[‡‡], Robert G. Raskin[§§], Paul Sutton[||||] & Marjan van den Belt[¶¶]

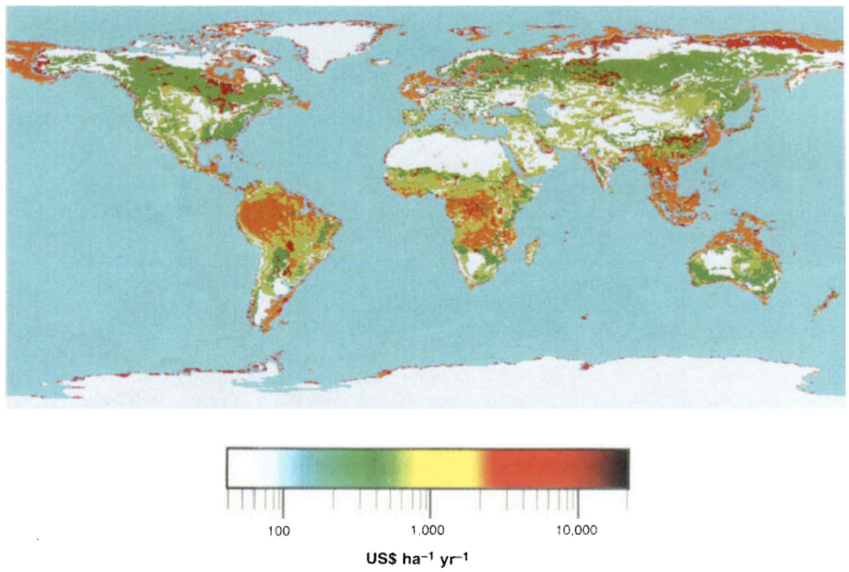


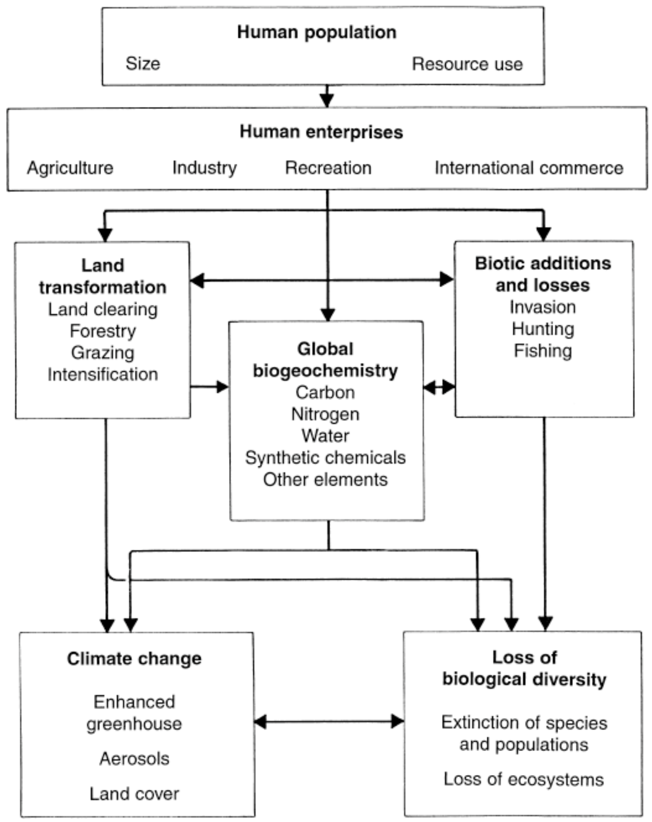
Figure 2 Global map of the value of ecosystem services. See Supplementary Information and Table 2 for details.

Human Domination of Earth's Ecosystems

Peter M. Vitousek, Harold A. Mooney, Jane Lubchenco, Jerry M. Melillo

Human alteration of Earth is substantial and growing. Between one-third and one-half of the land surface has been transformed by human action; the carbon dioxide concentration in the atmosphere has increased by nearly 30 percent since the beginning of the Industrial Revolution; more atmospheric nitrogen is fixed by humanity than by all natural terrestrial sources combined; more than half of all accessible surface fresh water is put to use by humanity; and about one-quarter of the bird species on Earth have been driven to extinction. By these and other standards, it is clear that we live on a human-dominated planet.

Fig. 1. A conceptual model illustrating humanity's direct and indirect effects on the Earth system [modified from (*56*)].



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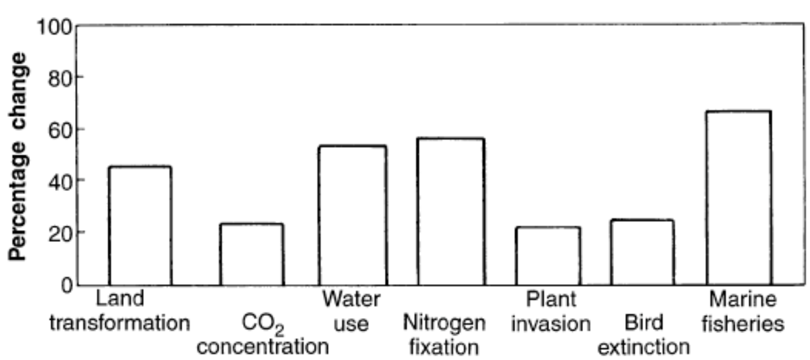


Fig. 2. Human dominance or alteration of several major components of the Earth system, expressed as (from left to right) percentage of the land surface transformed (*5*); percentage of the current atmospheric CO_2 concentration that results from human action (*17*); percentage of accessible surface fresh water used (*20*); percentage of terrestrial N fixation that is human-caused (*28*); percentage of plant species in Canada that humanity has introduced from elsewhere (*48*); percentage of bird species on Earth that have become extinct in the past two millennia, almost all of them as a consequence of human activity (*42*); and percentage of major marine fisheries that are fully exploited, overexploited, or depleted (*14*).

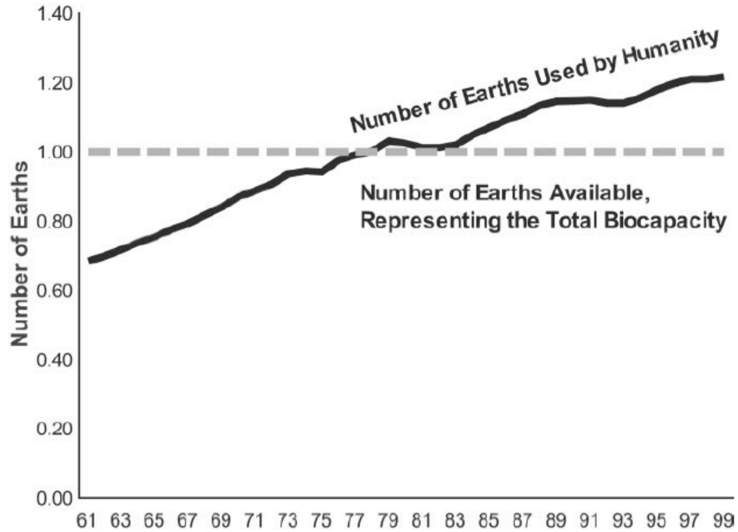
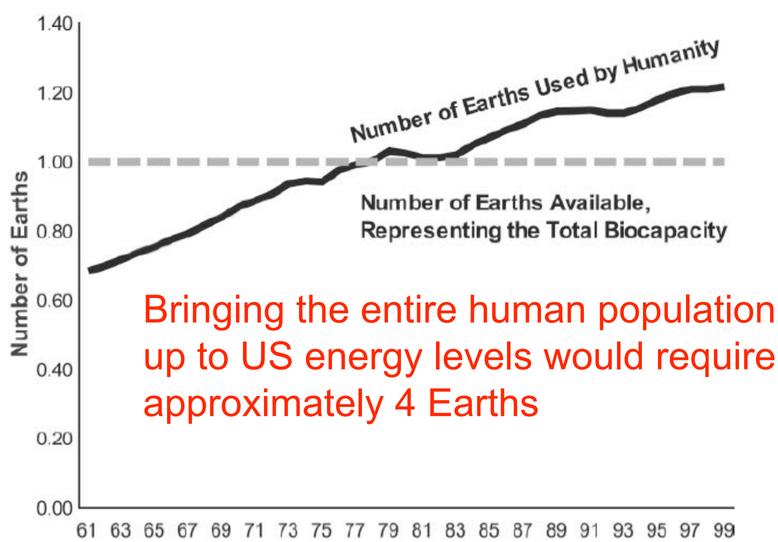


Fig. 1. Time trend of humanity's ecological demand. This graph shows human demand over the last 40 years as compared with the earth's ecological capacity for each year. One vertical unit in the graph corresponds to the entire regenerative capacity of the earth in a given year. Human demand exceeds nature's total supply from the 1980s onwards, overshooting it by 20% in 1999. If 12% of the bioproductive area were set aside to protect other species, the demand line crosses the supply line in the early 1970s rather than the 1980s.

The ONE - EARTH problem…



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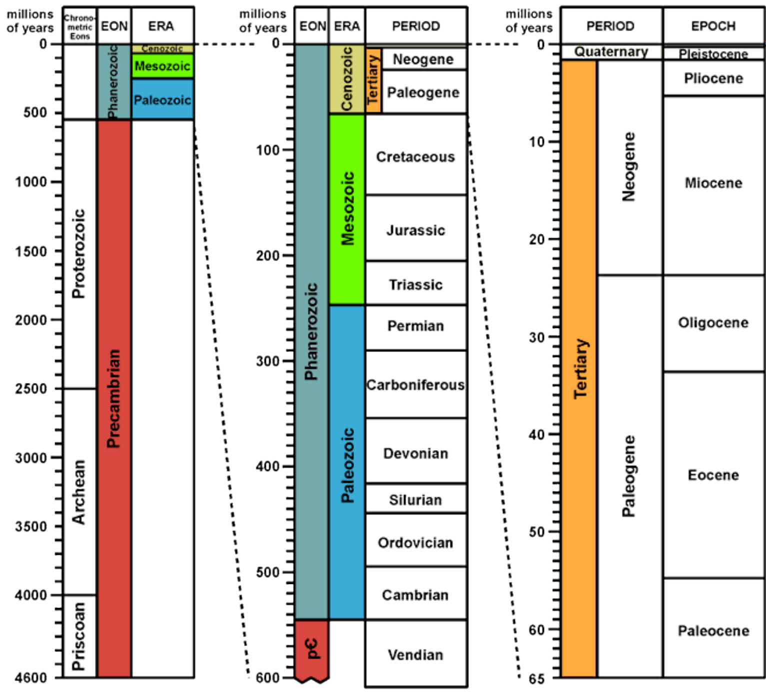
Is it the dawning of a new epoch?

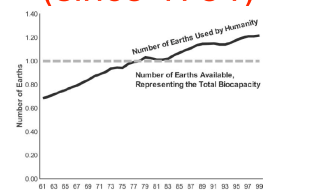
Anthropocene?
(since 1784)

GEOLOGIC TIME SCALE
(Based on data from Gradstein and Ogg, 1996 (Phanerozoic); and Harland et al., 1990)



copyright A. MacRae 1998

References:
Harland, W.B. *et al.*, 1990. A Geologic Time Scale, 1989 edition. Cambridge University Press: Cambridge, 263pp. ISBN 0-521-38765-5



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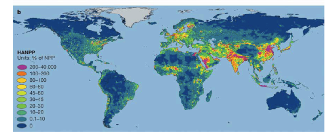
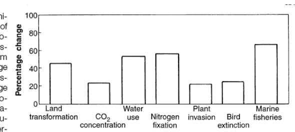


Figure 1 Spatial distribution of the annual NPP resources required by the human population. As measured by **a**, HANPP and **b**, HANPP as a percentage of local NPP. Both maps use the intermediate estimate for HANPP and are in units of carbon.



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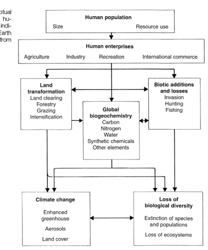

Fig. 1. A conceptual model illustrating humanity's direct and indirect effects on the Earth system [modified from (*56*)].

Where do we go from here?