Biodiversity Theory

Lecture notes by: Sima Fakheran

14 December 2010

2010

International Year of Biodiversity

Some questions about biodiversity

- What is biodiversity?
- Why Measure Diversity?
- Does biodiversity have values? Which values?
- How can we measure biodiversity?

Some definitions

Biodiversity is, broadly speaking, the **variety of life**. In principle, it can be assessed at any hierarchical level, including **genes, species, functional groups, or even habitats or ecosystems or landscapes.**

Definition of biodiversity

- There is considerable controversy about the definition of biodiversity. However, it is generally clear what is meant by the term in a particular context. And it is necessary to define the term for each particular context.

Level: genes, individuals, populations, communities, ecosystems, landscapes

Scale: local, regional, global; alpha, beta, gamma

Some definitions

Richness–the **number** of entities at a particular hierarchical level (e.g. species richness is the number of species).

Diversity is sometimes used in the specific sense to account for **both the number of entities and the evenness** with which those entities are represented. In practice the term is often used in the more general sense to be interchangeable with richness.

Species diversity at continental scales

insight review articles

Global patterns in biodiversity

Kevin J. Gaston

Biodiversity and Macroecology Group, Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, UK (e-mail: k.j.gaston@sheffield.ac.uk)

To a first approximation, the distribution of biodiversity across the Earth can be described in terms of a relatively small number of broad-scale spatial patterns. Although these patterns are increasingly well documented, understanding why they exist constitutes one of the most significant intellectual challenges to ecologists and biogeographers. Theory is, however, developing rapidly, improving in its internal consistency, and more readily subjected to empirical challenge.

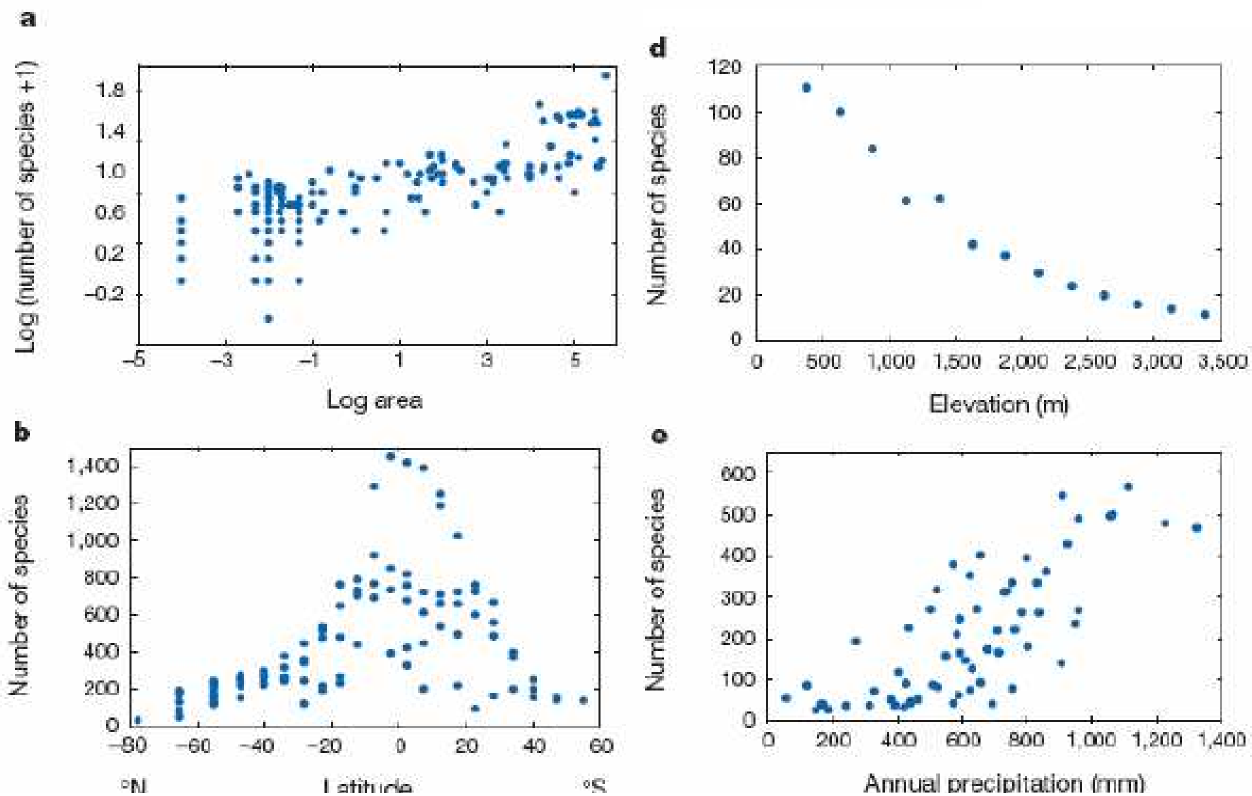


Figure 1 Spatial patterns in species richness. **a**, Species–area relationship: earthworms in areas ranging from 100 m² to >500,000 km² across Europe[79]. **b**, Species–latitude relationship: birds in grid cells (~ 611,000 km²) across the New World[44]. **c**, Relationship

lakes[61]. **d**, Species–elevation relationship: bats in Manu National Park & Biosphere Reserve, Peru[77]. **e**, Species–precipitation relationship: woody plants in grid cells (20,000 km²) in southern Africa[78].

Why Measure Diversity?

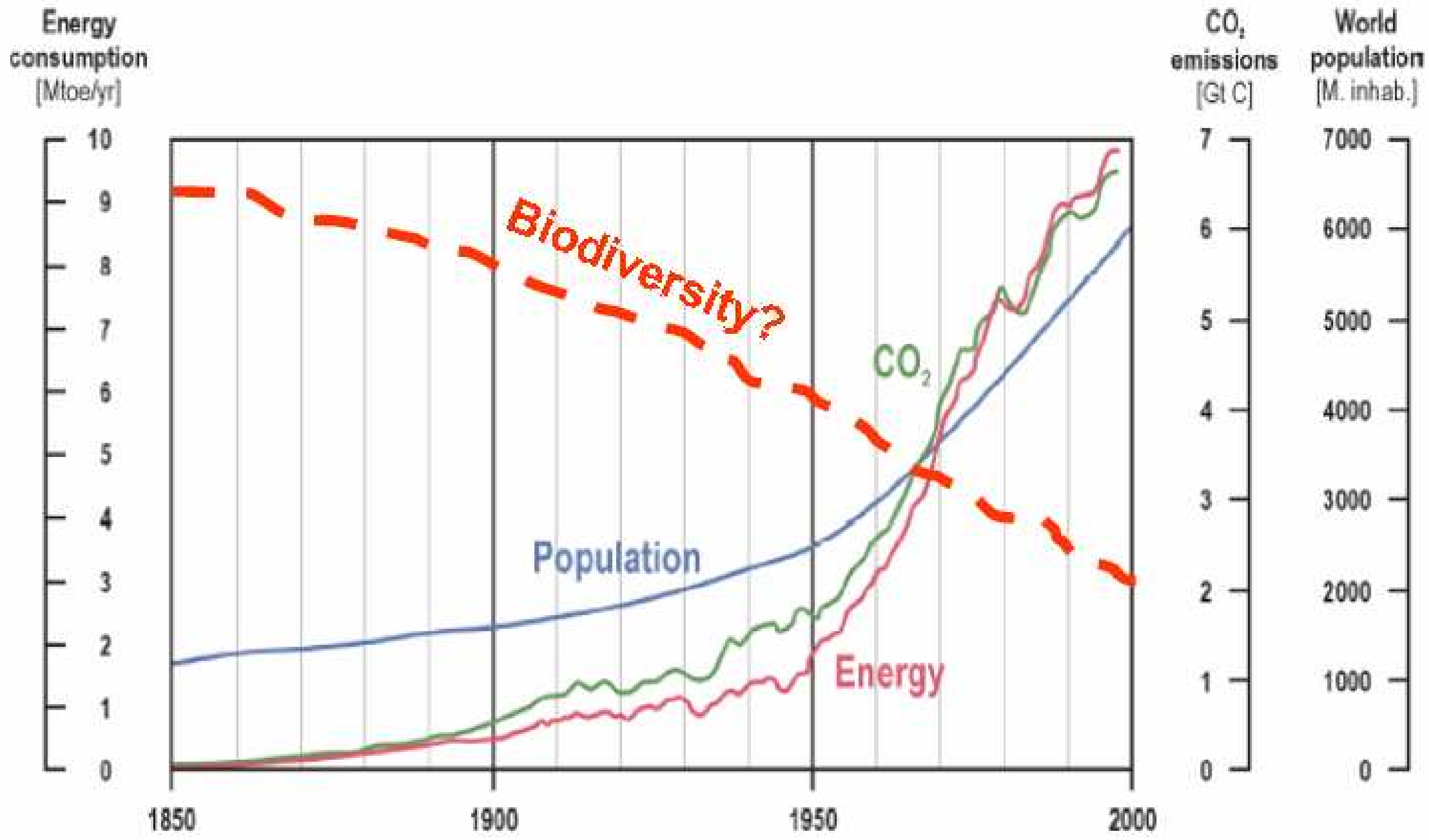
Biological diversity forms the basis of many ecological studies.

Many studies have used a wide range of techniques to quantify diversity.

These have included studies focused on patterns of species number in both **time and space**.

In addition, diversity measurement plays a critical role in **the study of human impacts on biological systems**. Its uses in conservation include estimation of extinction rates due to habitat loss, climate change, disturbance, and use as a barometer of ecosystem status

The human influence on the global environment



ECONOMIC VALUE OF BIODIVERSITY, MEASUREMENTS OF

Robert Mendelsohn
Yale University

Biodiversity as resource for humans

Food:

— 70'000 edible, 7'000 used, 150 clutivated plar species

— domesticated animals, fisheries, game

Buiding materials, textiles, energy:

— wood and fiber

— biomass fuel (estimated potential 20% of tota need)

Medical products and genes:

— 118 of the most important 150 drogues

— all genes for biotechnological applications

Non-material goods:

— aestetics, inspiration, recreation (tourism)

— art, science, education, cultural heritage

Gretchen Daily* and Shamik Dasgupta[†]
*Stanford University and [†]University College London

Production of Goods

Food
- Terrestrial animal and plant products
- Forage
- Seafood
- Spices

Pharmaceuticals
- Medicinal products
- Precursors to synthetic pharmaceuticals

Durable materials
- Natural fiber
- Timber

Energy
- Biomass fuels
- Low-sediment water for hydropower

Industrial products
- Waxes, oils, fragrances, dyes, latex, rubber, etc.
- Precursors to many synthetic products

Genetic resources
- Which enhance the production of many of these goods

Life-Fulfilling Functions
- Aesthetic beauty
- Cultural, intellectual, and spiritual inspiration
- Existence value
- Scientific discovery
- Serenity

Biodiversity and Agriculture

Case study 2: biodiversity and agriculture

Darwin & Wallace 1858: *"We know that it has been experimentally shown that a plot of land will yield a greater weight if sown with several species and genera of grasses, than if sown with only two or three species."*

Harper 1977: *"The general conclusion is that there is no advantage to a farmer in sowing a mixture of grass species if his aim is to maximize dry matter production under ideal and constant conditions."*

"If there is uncertainty, the mixture will on average give higher yields than a pure stand."

Insurance value of biodiversity

- **Payments for environmental services:**

Economy & Biodiversity

Interconnectedness of World Problems

Environmental Economics

The Tragedy of the Commons

Garrett Hardin – *The Tragedy of the Commons*, article in *Science* (1968)

Even so, multiple individuals acting in their own **self-interest** can destroy a **shared resource** (*e.g.*, a **"commons"**)

Environmental Economics

Garrett Hardin – *The Tragedy of the Commons*,
article in *Science* (1968)

The **"commons"** was used as a metaphor for the Earth and its growing human population

Elinor Ostrom (first woman to win Nobel Prize in Economics – 2009) has shown that on the small-scale, the tragedy is often avoided by cooperation among the commons' users, who impose sanctions, *etc*. on those who cheat

Journal cover from the 12 December 2003 issue of *Science*; www.sciencemag.org

- The **tragedy of the commons** is a dilemma arising from the situation in which multiple individuals, acting independently, and solely and rationally consulting their own self-interest, will ultimately deplete a shared limited resource even when it is clear that it is not in anyone's long-term interest for this to happen.

- The herders are assumed to wish to maximize their yield, and so will increase their herd size whenever possible. The utility of each additional animal has both a positive and negative component:

- **Positive**: the herder receives all of the proceeds from each additional animal.

- **Negative**: the pasture is slightly degraded by each additional animal

Examples of Tragedies of the Commons

- **Harvesting timber on public land**:

  each tree cutter knows that a tree not harvested this year will be bigger, and hence more valuable, next year.

  But he also knows that if he doesn't cut the tree down this year, someone else will

examples

People don't harvest blackberries to soon from their backyard garden.

People don't dump toxic wastes into their own swimming pools.

- Other situations exemplifying the "tragedy of the commons" include **pollution caused by driving cars**. There are many negative externalities of driving; these include, carbon emissions, and traffic accidents.

- For example, every time 'Person A' gets in a car, it becomes more likely that 'Person Z' – and millions of others – will suffer in each of those areas.

– population growth

– Air, whether ambient air polluted by industrial emissions and cars among other sources of air pollution, or indoor air.

– Water - Water pollution, Water crisis of over-extraction of groundwater and wasting water due to overirrigation

– Forests
– Energy resources and climate - Burning of fossil fuels and consequential global warming
– Animals - Habitat destruction and poaching leading to
– Oceans – Overfishing.

Present Value and Discounting

How many of you would rather receive
$100 today vs. the equivalent of $100 in a year's time?

Costs and benefits often change value over time

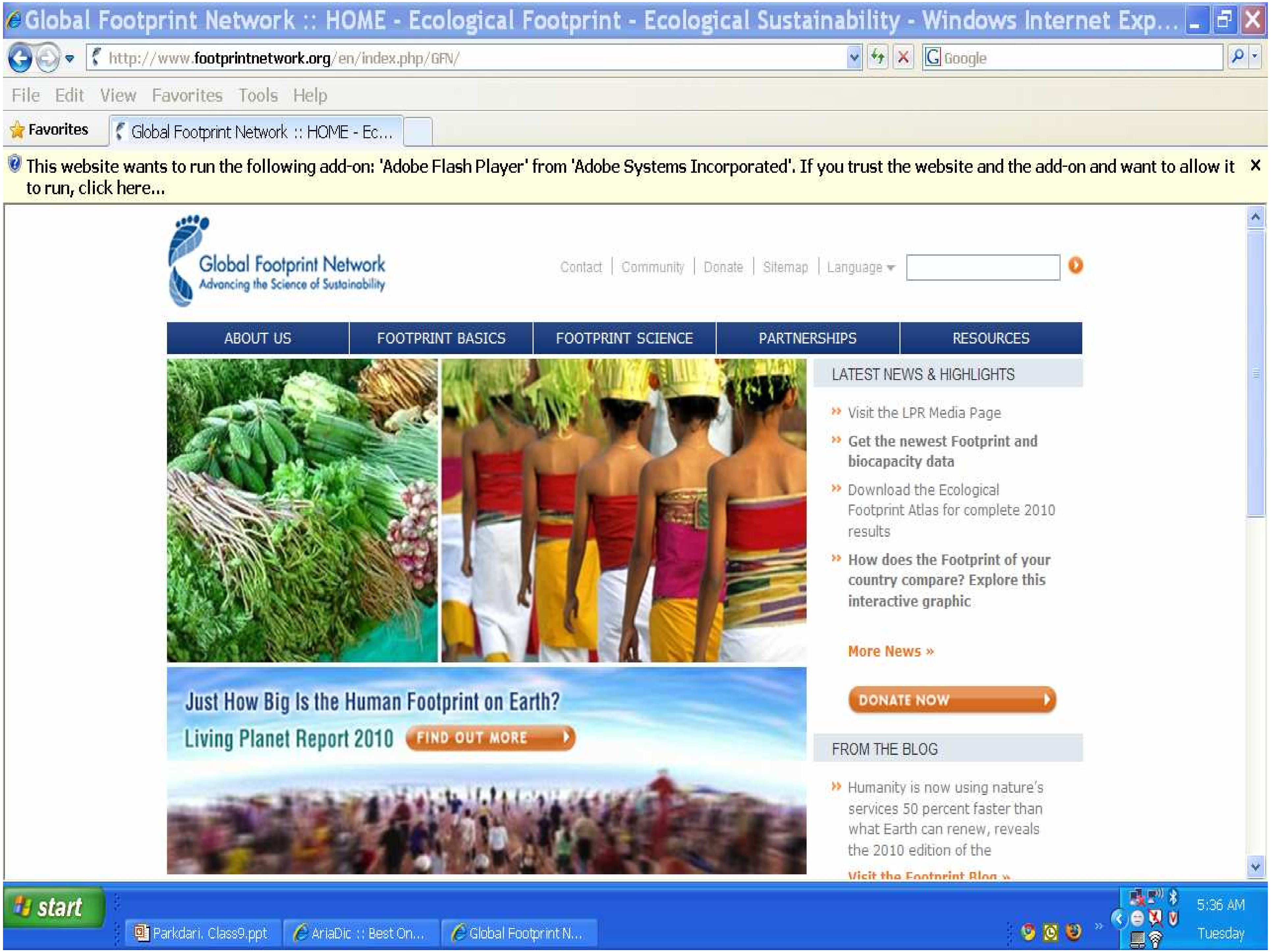
The general preference to receive good things now (and put bad things off until later) is called **time preference**

Many economists advocate converting all future costs and benefits to **present value**; future sums of money are **discounted** by a rate that reflects time preference

- The fundamental assumption in discounting is that future costs and benefits are less important than current ones.

- Remember, discounting is entirely separate from the process of adjusting for **inflation** – which is a rise in the general level of prices of goods and services and results in eroded purchasing power for a given unit of currency.

- The environment and the economy are closely interrelated and affect not only each other but also the welfare of people; therefore, environmental issues have to be taken into account when designing economic policies and vice versa.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Living Planet Report 2010
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FROM THE BLOG
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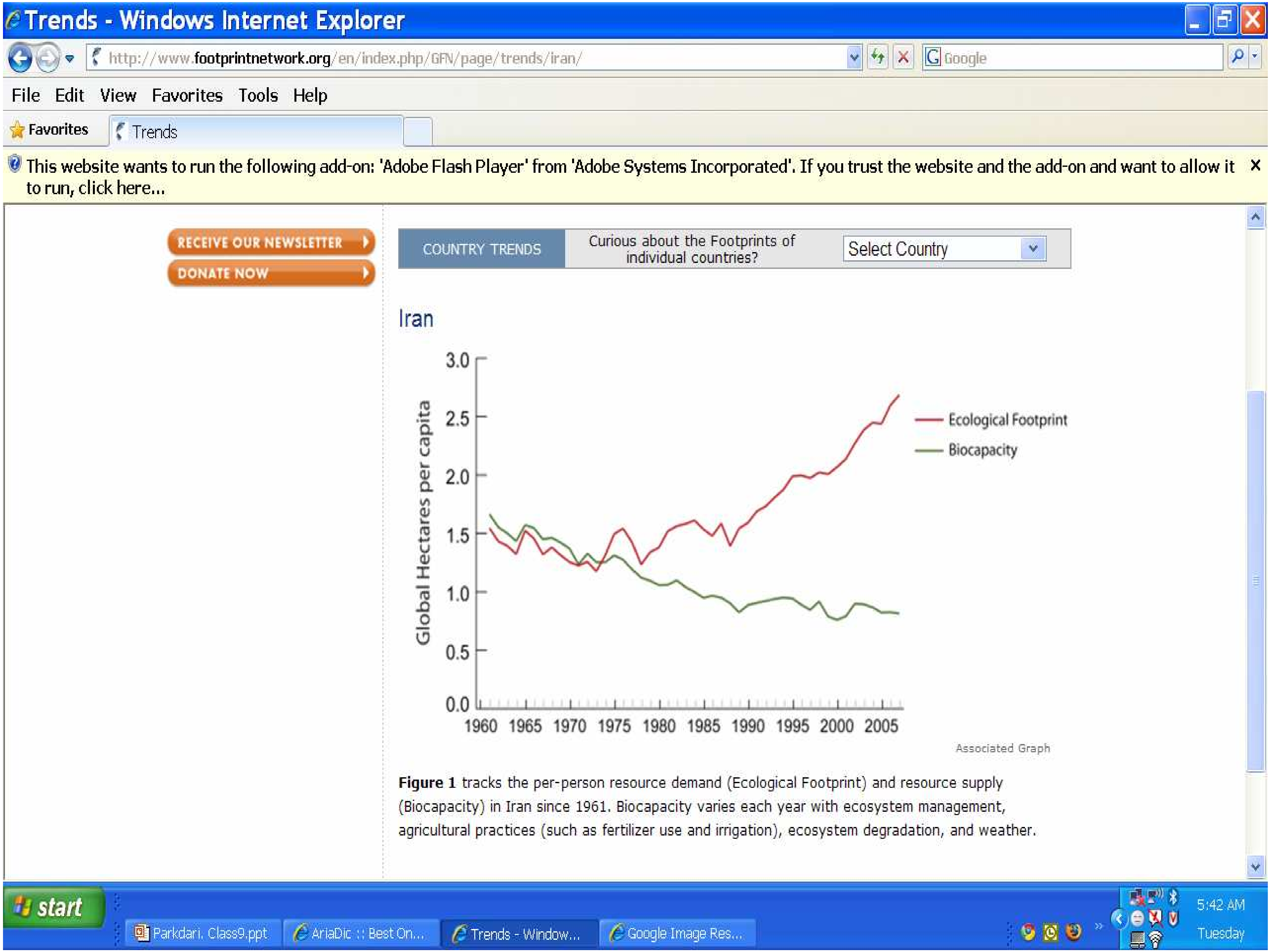
- ***How BIG*** is Your ***Ecological Footprint***?


HELP!
BIGFOOT!

Man's footprint on the planet today.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Iran
Global Hectares per capita
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
Ecological Footprint
Biocapacity
Associated Graph
Figure 1 tracks the per-person resource demand (Ecological Footprint) and resource supply (Biocapacity) in Iran since 1961. Biocapacity varies each year with ecosystem management, agricultural practices (such as fertilizer use and irrigation), ecosystem degradation, and weather.
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Personal Footprint - Windows Internet Explorer

http://www.footprintnetwork.org/en/index.php/GFN/page/personal_footprint/

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Favorites | Personal Footprint

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IN THIS SECTION

- Introduction
- Overview
- World Footprint
- Footprint for Nations
- Ecological Creditors and Debtors
- Our Human Development Initiative
- The Footprint and Biodiversity
- Footprint for Cities
- Footprint for Business
- Carbon Footprint
- » **Personal Footprint**
  - Footprint Calculator Frequently Asked Questions
- Frequently Asked Questions

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Personal Footprint

How much land area does it take to support your lifestyle? Take this quiz to find out your Ecological Footprint, discover your biggest areas of resource consumption, and learn what you can do to tread more lightly on the earth.

Take the Quiz

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Some questions about biodiversity

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Shannon's diversity index

Shannon-Weaver

- **H'= Σpi ln(pi)**

- The Shannon index takes the number of species and the evenness of the species into account and increases either by having additional unique species, or by having greater species evenness.

- 1.5 – 4
- max 5

Shannon Index

Called alternatively Shannon-Weaver, Shannon-Wiener, or Shannon Index

Derived by Claude Shannon and Warren Weaver in late 40s

Developed a general model of communication and information theory

Subsequently mathematician Norbert Wiener contributed to the model as part of his work in developing cybernetic technology

Simpson Index (D)

$D = \Sigma pi^2$

Simpson`s index of diversity= 1- D

The Simpson Index gives the probability that two individuals drawn at random from a community belong to the same species (Simpson 1949).

0-1

Margalef's richness index:

(S-1)/ ln (n)

where

S is the number of taxa,

n is the number of individuals

See also:

Berger-Parker index

alpha, beta & gamma diversity

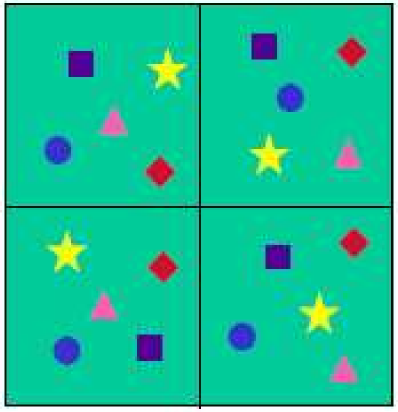
- *Alpha diversity* refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (i.e., *species richness*) in that ecosystem

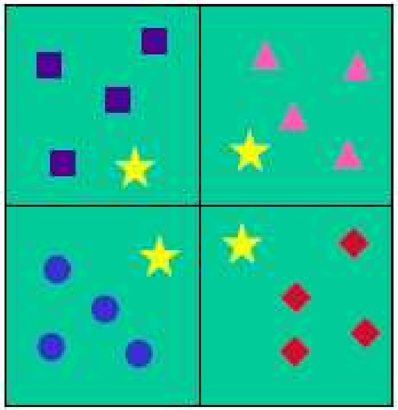
- *Beta diversity* a comparison of of diversity between ecosystems, usually amount of species change between the ecosystems

- *Gamma diversity* is a measure of the overall diversity for the different ecosystems within a region.

Hypothetical species	Habitat 1	Habitat 2	Habitat 3
A	X		
B	X		
C	X		
D	X		
E	X		
F	X	X	
G	X	X	
H	X	X	
I	X	X	
J	X	X	
K		X	
L		X	X
M			X
N			X
Alpha diversity	10	7	3
Beta diversity	Habitat 1 vs. habitat 2 : **7**	Habitat 2 vs. habitat 3: **8**	Habitat1 vs. habitat 3: **13**
Gamma diversity	14		

Alpha- and beta-diversity





Ecology Letters, (2002) 5: 433–444

REPORT

The alpha–beta–regional relationship: providing new insights into local–regional patterns of species richness and scale dependence of diversity components

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Abstract
Ecologists frequently regress local species richness on regional species richness to draw inferences about the processes that structure local communities. A more promising approach is to quantify the contributions of alpha and beta diversity to regional diversity (the ABR approach) using additive partitioning. We applied this approach to four local–regional relationships based on data from 583 arboreal beetle species collected in a hierarchically nested sampling design. All four local–regional relationships exhibited proportional sampling, yet the ABR approach indicated that each was produced by a different combination of alpha and beta richness. Using the results of the ABR analysis, we also analysed the scale dependence of alpha and beta using a hierarchical linear model. Alpha diversity contributed less than expected to regional diversity at the finest spatial scale and more than expected at the broadest spatial scale. A switch in relative dominance from beta to alpha diversity with increasing spatial scale suggested scale transitions in ecological processes. Analysing the scale dependence of diversity components using the ABR approach furthers our understanding about the additivity of species diversity in biological communities.

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Partitioning Species Diversity across Landscapes and Regions: A Hierarchical Analysis of α, β, and γ Diversity

Thanks for your attentions!