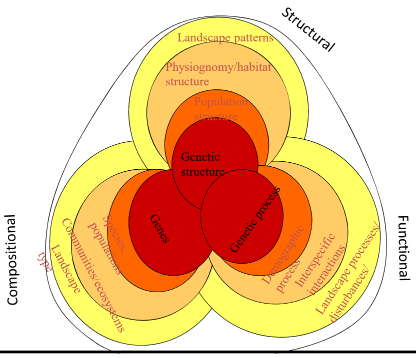
What is Biodiversity?

- The **variety of different types of organisms** present and interacting in an ecosystem, biome, or on the entire Earth.
- This includes all the different
  - plants
  - animals
  - fungus
  - microorganisms
  - Their genes
  - and the ecosystem that they form part of

1

Biodiversity: 3 aspects x 3 levels



(Noss 1994)

2

What is Biodiversity?

- Often **more species equals more diversity**, although there are, in fact many more factors beyond a simple count of species that determine whether biodiversity is higher or lower in any given ecosystem.
- Takes into account the **number of different species** and the **numbers of individuals**
  - **heterogeneity of species**
    - equitability or evenness
    - relative abundance of each species present in the community

3

At any level, diversity has at least two components…

- **How many different types of things are present**
  - Elephant, rhino and lion **is less diverse** than
  - Elephant, rhino, lion, leopard and buffalo
- **How evenly they are represented**
  - 1000 elephants and 1 lion **is less diverse** than
  - 500 elephants and 500 lions

4

Definitions

- **Ecosystem**
  - All **Biotic** (living) and **Abiotic** (non living factors)
- **Species**
  - Organisms with similar appearance, anatomy, physiology, biochemistry and genetics that can interbreed freely to produce **fertile offspring**
- **Habitat**
  - Where individuals of a species live
  - Specific locality, with specific conditions that species may be well adapted to

5

6

7

Levels of Biodiversity

- Genetic Diversity
- Species Diversity
- Ecosystem Diversity

Other attributes:

- Trophic structure
- Evolutionary diversity
- Within species diversity (morphological, chemical)

8

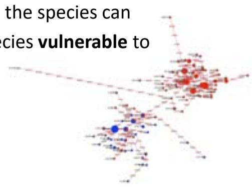
Genetic Diversity

- **Amount and variety of genetic material** within individuals, populations or communities
- **Source of biodiversity** at all levels
- Knowledge of amount of genetic variability present within local populations **essential in directing conservation programs**
- Amount of genetic differences among species could help determine **rates of evolutionary change**

9

Genetic Diversity

- Species need **variation** within their genes
- These differences are called **alleles**
  - E.g. tongue rolling and non tongue rolling
- Variation improves a species likelihood of **adapting** if the environment changes
  - Individuals cannot adapt but the species can
- **Lack of variation** makes the species **vulnerable** to extinction if conditions change



10

Species Level

- **Species Richness**: numerical count of species present in an area. Richness tends to increase over area and sampling intensity
- **Species Diversity**: When species are weighted by some measure of importance e.g. abundance, productivity or size
- **Measures of Species Diversity include:**
  - Shannon-Wiener Index
  - Simpson Index

11

'Academic' ways of measuring biodiversity

Species level
- Richness: Total number of species in an area (α diversity)
- Species turnover along a gradient (β diversity)

Ecosystem level
- Number of different habitats or ecosystems (γ diversity)

Genetic level
- Genetic homology
- Cladistic distance

12

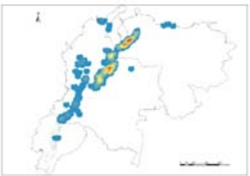
'Policy' ways of measuring biodiversity

- **'Extinction based' (IUCN)**
  - Threatened species (Red Data Books)
- **'Area based' (Millennium goals)**
  - Area under protection
  - Area of a key habitat (e.g. Forest cover)
- **'Richness based'**
  - Indicator groups or species e.g. CI Rapid Biodiversity Assessment
- **Complementarity-based**
  - Various conservation optimisation tools, e.g. CPLAN
- Various **spatial representations**
  - Hotspots, last wild places

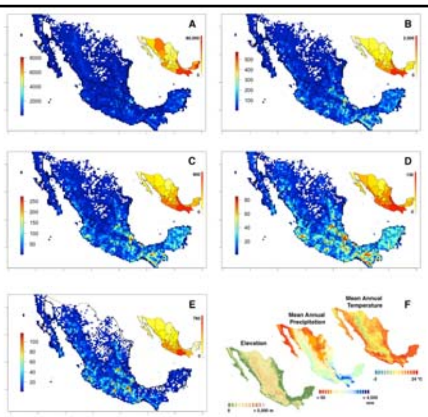
13

Species richness

- This is the number of species in a habitat
- The more species the richer the habitat
- However this doesn't give us the full picture of biodiversity – what if there are only a few individuals of a couple of a species – that habitat doesn't have a high biodiversity



14



15

Species evenness

- This is a measure of the abundance of individuals in a species.
- This is a **QUANTITATIVE** assessment as it gives relative numbers of each species present

16

Abundance can be measured…

- **Percentage cover** – the proportion of each quadrat occupied by the species
- **Population density** – the number of individuals per quadrat
- **Species frequency** – the proportion of quadrats with the species in it

17

Measurement of species diversity

- **Heterogeneity of species**
  - uses relative abundance to give more weight to common species
  - possibilities in a 2-species community:

	Comm 1	Comm 2
Species A	99	50
Species B	1	50
	100	100

18

18

Shannon-Wiener Diversity Index

- Assume that there are n possible categories in a data set and that their proportions are p_i ,....., p_n. Then Shannon's diversity index for this system is defined to be:

$$H' = -\Sigma p_i \ln(p_i)$$

- accounts for both abundance and evenness of the species present
- The proportion of species *i* relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$).

19

Shannon-Wiener diversity index

Community 1				
Species	N	p_i	$\ln(p_i)$	$p_i [(\ln(p_i)]$
A	99			
B	1			
Community 2				
Species	N	p_i	$\ln(p_i)$	$pi[(\ln(p_i)]$
A	50			
B	50			

20

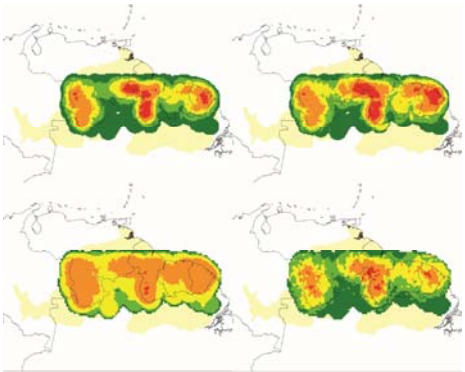
20

Shannon-Wiener diversity index

Community 1				
Species	N	p_i	$\ln(p_i)$	$p_i [(\ln(p_i)]$
A	99	0.99	-0.010	-0.010
B	1	0.01	-4.605	-0.046
	100	1.00		-0.056
H'				0.056
Community 2				
Species	N	p_i	$\ln(p_i)$	$p_i [(\ln(p_i)]$
A	50	0.50	-0.693	-0.347
B	50	0.50	-0.693	-0.347
	100	1.00		-0.694
H'				0.694

21

21



22

Simpson's Diversity Index, D

- Simpson's diversity index (*D*) characterizes species diversity in a community.

$$D = 1/(\Sigma p_i^2)$$

- The proportion of species *i* relative to the total number of species (p_i) is calculated and squared. The squared proportions for all the species are summed, and the reciprocal is taken.
- The scale ranges from 0–1, with 1 representing the lowest biodiversity.

23

Biodiversity at Sites in Honduras

The following calculations are based on sampling conducted in Honduras by Canadian Museum of Nature research scientist Bob Anderson.

Site	N	N(N - 1)	∑ n(n - 1)	D	Species Richness
Cerro Montecristo	2996	7 120 892	1 600 002	0.2247	61
El Pital 2050 m	233	54 056	6856	0.1268	22
El Pital 2650 m	5411	29 273 510	12 873 694	0.4398	46
Cerro Puca	311	96 410	19 126	0.1984	27
Santa Barbara	839	703 082	55 514	0.0789	44

24

Simpson's Diversity Index

- A more diverse habitat should be less susceptible to change if one species is affected, than a less diverse ecosystem which is dominated by one or two species

25

SAfMA* Biodiversity Intactness Index

- Based on impacts on populations, rather than extinctions
- Considers a range of impacts
  - Protected, sustainably used, unjust used, partially transformed, transformed
- Scale independent
- Applicable now, but amenable to incremental improvement

Millennium Ecosystem Assessment
Strengthening Capacity to Manage Ecosystems Sustainably for Human Well-Being

*Southern Africa Millennium Ecosystem Assessment

26

SAfMA Algorithm

$$B = \left(\sum_{j=1}^{m}\sum_{i=1}^{t}\sum_{k=1}^{n} C_{ijk}A_{jk}R_{ij}\right) / \left(\sum_{j=1}^{m}\sum_{i=1}^{t} A_{j}R_{ij}\right)$$

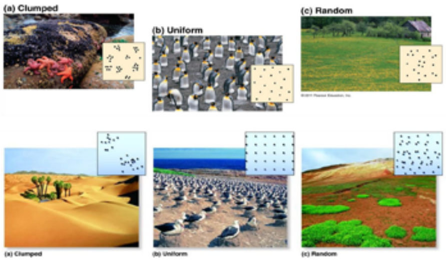
B = biodiversity intactness index
C_{ijk} = populations of i under use k/ popn when protected
A_{jk}= Area of land use k in ecosystem j
R_{ij} = Richness of taxon i in ecosystem j
i= taxon, from 1 to t
j= ecosystem, from 1 to m
k= land use type, from 1 to n

Needs: Land cover, richness, impact matrix

27

Individual-Based

- The first approach is to examine some number of individuals at random within each environment, recording sequentially the species identity of one individual after another.



28

Sample-Based

- Alternatively, one could establish a series of quadrats in each plot, record the number and identity of all the trees within each, and accumulate the total number of species as additional quadrats are censused.

29

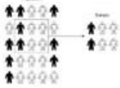
Why sampling?

- You can't practically count every single organism
- Sampling provides a representation of the number and distribution of an organism
- There must be sufficient number of samples for the results to be representative of the situation

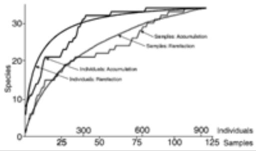
30

Taxon sampling curves

- We distinguish four kinds of taxon sampling curves, based on two dichotomies:
  - **Sampling protocol:**
    1. individual-based
    2. sample-based



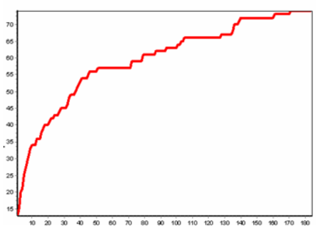
  - **Curves**
    1. accumulation curves
    2. rarefaction curves.



31

Accumulation curves

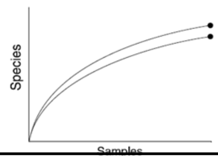
- During the process of data collection, as additional individuals or sample units are added to the pool of all previously observed or collected individuals or samples.



32

Rarefaction curves

- Produced by repeatedly re-sampling the pool of N individuals/ samples, at random
- Plotting the average number of species represented by 1, 2, .., N individuals/ samples
- Sampling is generally done without replacement, within each re-sampling.
- Rarefaction generates the expected number of species



33

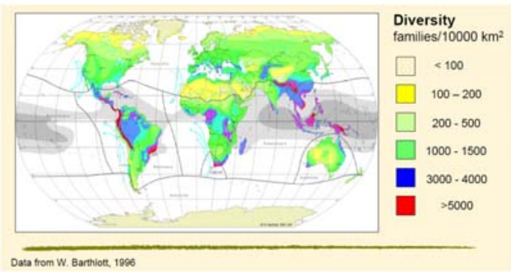
Patterns of Species Diversity

- Latitudinal
  - Global pattern—drivers?
- Islands (but also mtn. tops, lakes, etc.)
  - Patterns with island size
    - Species-Area curves
  - Patterns with island size & distance
    - Theory of Island Biogeography
      - Predicting species diversity as a function of colonization and extinction rates
- Metapopulations*
  - Modern extension of island biogeography

*not related to diversity

34

Global patterns of species diversity (land plants)



35

Temporal Patterns of Species richness

- Fossil record indicate variation of species richness over time and space
- Largest number of phyla in the Cambrian and pre-Cambrian period
- Total number of phyla has since declined but overall richness has increased

36

Spatial patterns of species richness

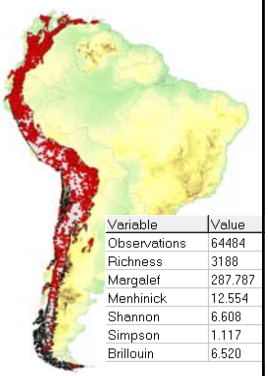
- **Point richness**: number of species that can be found in a single point in space
- **Alpha (α-) richness**: number of species found in a small homogenous area
- **Beta (β-) richness**: rate of change in species in species composition across habitats
- **Gamma (γ-) richness**: change across large landscape gradients or islands
- **Richness** is directly related to physical environment, productivity and structural complexity of communities

37

38

Occurrences:
- 317.195 data (7 countries)
- 177.661 georeferenced
- 148.750 at spp. level
- **64.484** with spp. & georef.
- 3.188 species
- 404 genera

Variable	Value
Observations	64484
Richness (S)	3188
Chao-1	3920.377
Chao-2	3917.497
Jacknife-1	3936.765
Jacknife-2	4685.175
ACE	3214.712



Variable	Value
Observations	64484
Richness	3188
Margalef	287.787
Menhinick	12.554
Shannon	6.608
Simpson	1.117
Brillouin	6.520

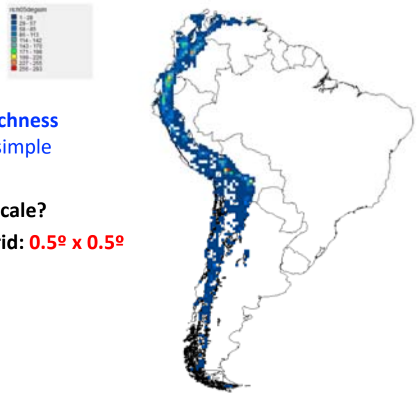
39

Country	No. de obs.	No. de spp.	No. spp. end.	No. de gen.	No. gen. end.
Argentina	1.132	431	148 (34%)	124	12 (10%)
Bolivia	7.976	952	402 (42%)	232	23 (10%)
Chile	1.422	424	249 (59%)	101	18 (18%)
Colombia	32.681	980	499 (51%)	221	26 (12%)
Ecuador	12.343	847	327 (39%)	201	9 (4%)
Peru	6.886	970	428 (44%)	221	14 (6%)
Venezuela	2.044	329	131 (40%)	128	14 (11%)
TOTAL	64.484	3.188	2.184 (68%)	404	116 (29%)

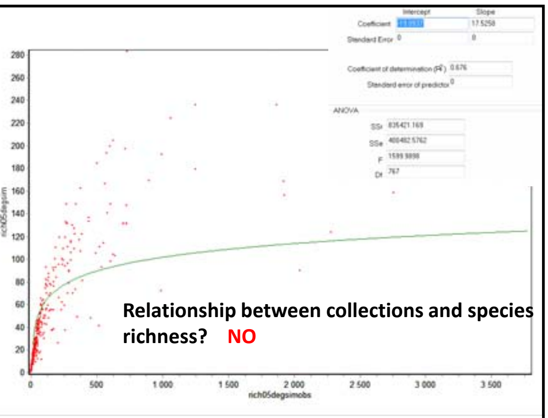
40

Species richness
Method: simple

Effect of scale?
Grid: 0.5º x 0.5º

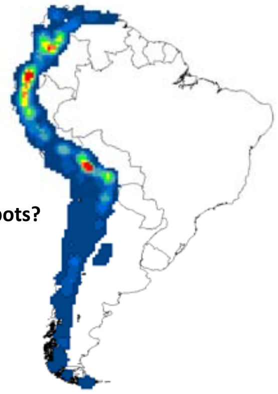


41



Relationship between collections and species richness? NO

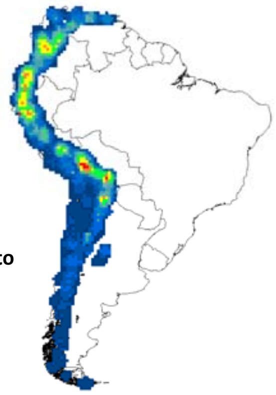
42

Species richness
Method: circular
Grid: 0.5º x 0.5º

Richness centres or hotspots?

43

Richness pattern of genera?

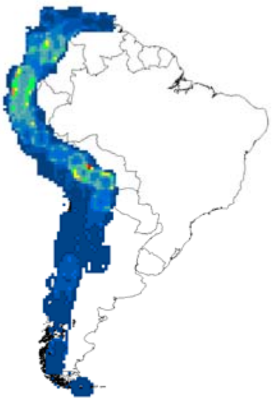
Genera richness
Method: circular
Grid: 0.5º x 0.5º

Genera richness similar to estimated richness?

Chao-1 Corrected

Correlation between species and generic richness?

44

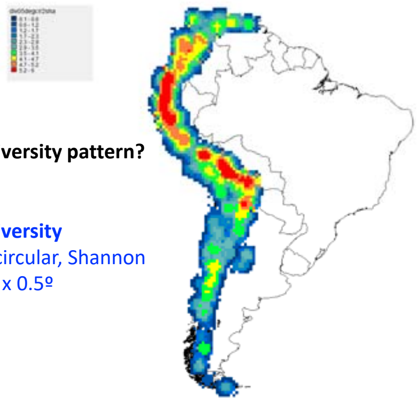



Turnover rate between species?

Species turnover
Method: Queen
Grid: 0.5º x 0.5º

45

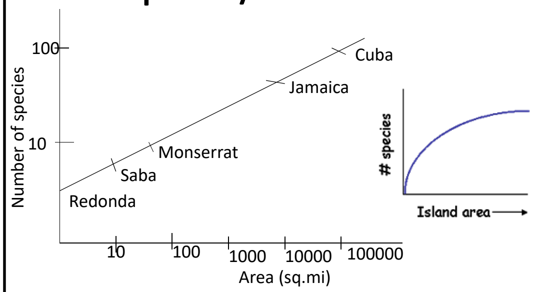
Species diversity pattern?



Species diversity
Method: circular, Shannon
Grid: 0.5º x 0.5º

46

Species / Area relations



Relationship between area and number of amphibian species in selected Islands in West Indies (MacArthur & Wilson 1967)

47

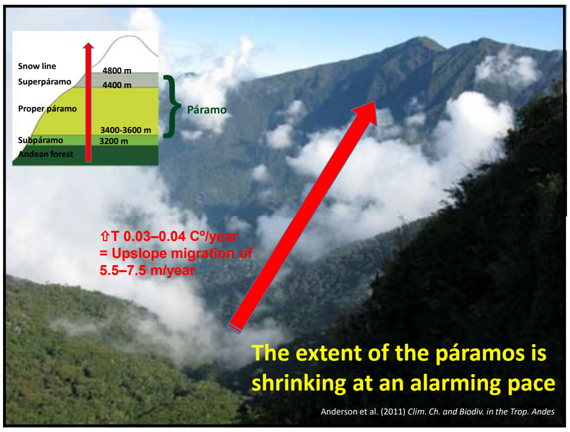
Threats to biodiversity

- **habitat destruction** (slash and burn agric. or felling of old-growth forests)
- **overexploitation** (fishing, hunting)
- **pollution** (domestic and industrial emissions)
- **invasion by introduced species** (displacement of native spp.)
- **underlying social conditions** (increased per-capita consumption, poverty, rapid population growth, unsound economic and social policies)

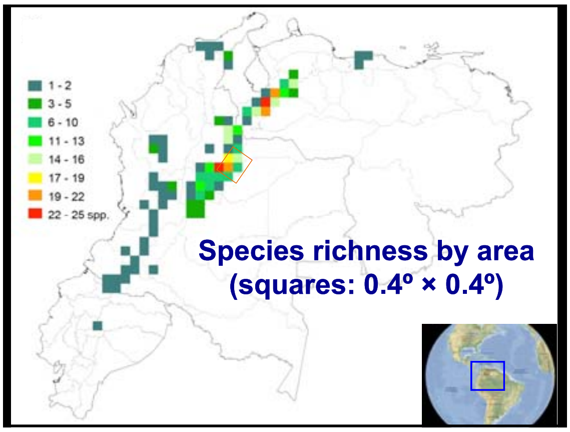
HIPPO: Habitat destruction, Invasive species, Pollution, human over-Population, and Over-harvesting

- **Global Climate Change** (the greenhouse effect and destruction of the ozone layer)

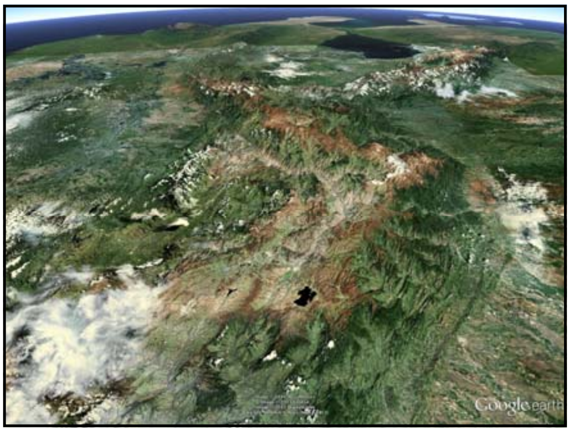
48


Snow line
Superpáramo
Proper páramo
Subpáramo
Andean forest
4800 m
4400 m
3400-3600 m
3200 m
Páramo
⇧T 0.03–0.04 C°/year
= Upslope migration of
5.5–7.5 m/year
The extent of the páramos is shrinking at an alarming pace
Anderson et al. (2011) *Clim. Ch. and Biodiv. in the Trop. Andes*

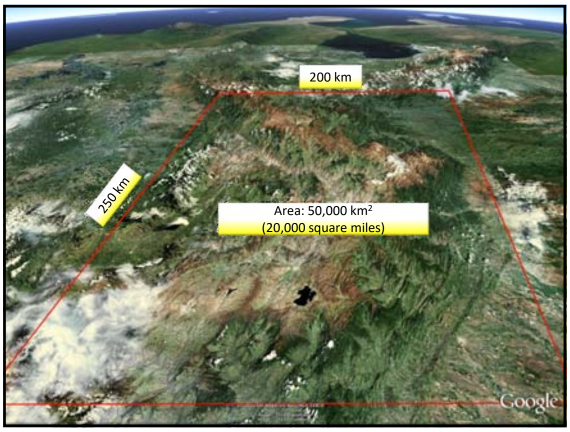
49


1 - 2
3 - 5
6 - 10
11 - 13
14 - 16
17 - 19
19 - 22
22 - 25 spp.
Species richness by area
(squares: 0.4º × 0.4º)

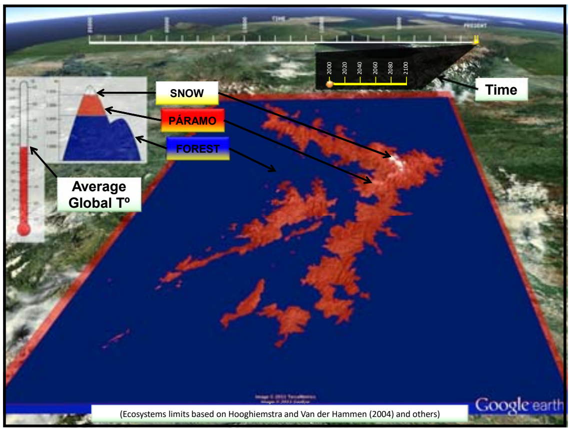
50



51

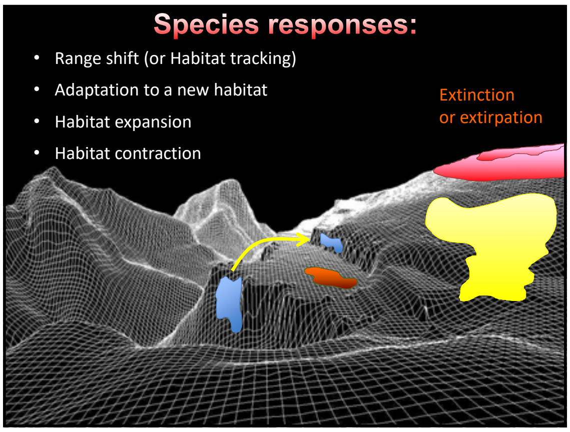

200 km
250 km
Area: 50,000 km²
(20,000 square miles)
Google

52


SNOW
PÁRAMO
FOREST
Time
Average
Global Tº
(Ecosystems limits based on Hooghiemstra and Van der Hammen (2004) and others)
Google earth

53

54



55

Patterns of species vulnerability

- **Rare Species**
- **Long-lived species**
- **Keystone species**

56

Rare species

- May be the result of many factors small range, high habitat specificity or small population density
- Human-induced rarity may be more damaging

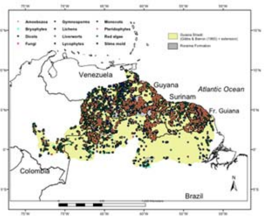
57

Biodiversity of the Guiana Shield Project

Databasing:

- Data compilation
- Nomenclature cleaning
- Georeferenciation

GIS: ArcMap, R and DIVA-GIS



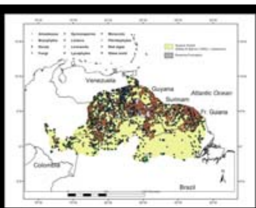
Number of collections

- Animals: 28,198
- Plants: 181,838

GROUPS	Specimens	Families	Genera	Species
Amoebozoa	6	3	4	3
Bryophytes	1,561	37	98	254
Dicots	111,082	174	1,563	9,539
Fungi	1,308	75	175	212
Gymnosperms	166	4	5	19
Lichens	2,523	50	134	362
Liverworts	446	17	50	58
Lycophytes	835	4	5	91
Monocots	29,065	43	508	2,915
Pteridophytes	10,077	30	107	802
Red algae	2	1	1	1
Slime mold	5	2	4	5
TOTAL	157,076	440	2,654	14,261

58

- **Guiana Shield: 181,838 plant collections, 14,261 species. Rare species: 43% (4,277 singletons and 1,855 doubletons). Below 10 collections: 10,510 species (73.7%)!**



- **COMPOSITAE FROM COLOMBIA**
  - **33,493 collections, 1,308 species, rare species 13.8% (68 singl. and 112 doubl.)**
  - **Below 10 collections: 667 species (51%)!**
- **Subtribe Espeletiinae**
  - **4,376 collections, 143 species, rare species 17.5% (19 singl. and 6 doubl.)**
  - **Below 10 collections: 70 species (48.9%)!**

59

Long-lived species

- Well-suited to long-term predictability
- Often not equipped to adapt to rapid changes brought by human-induced changes
- Often population declines may take many years to recover

60

Keystone species

- A species or group of species that makes and unusual contribution to a community structure or processes
- May be predators, food source or species that maintains critical ecosystem processes
- A loss of a keystone species may lead to loss of others that depend on it.

61

Biodiversity and global economy

- Globally **agriculture**, which depends on genetic stock from natural ecological systems, is now worth a **$3 trillion**
- **Recreation and nature tourism** generates some **$12 billion** worldwide in annual revenues
- In the United States, the economic benefits from **wild plants and animals** comprise approximately **4.5% of the Gross Domestic Product**.
- Global trade in **wild plants** (timber and others) is estimated at **$6 billion annually**

62

Biodiversity and global economy

- Much of the world's **major food crops**, including corn, wheat, and soybeans, depend on **new genetic material** from the wild to remain productive and healthy.
- Food production from **wild stocks of fish** is the single largest source of animal protein for the world’s 6+ billion inhabitants. In the US alone more than 10 billion pounds of fish, valued at about $4 billion, were caught and sold yearly.
- **Pollination**: 30% of 1,500 crop plant species depend on bee and other insect pollination. Value of bees for pollination ~ EUR 29-70 billion worldwide per annum
- **Flood control services of floodplain**: e.g. River Bassee floodplain: ~ 91.5 – 305 million EUR/year

63

Biodiversity and food security

64

65

66

Biodiversity as an Indicator

- Biodiversity => **health** of the ecosystem
- Biodiversity and **stability** relationship
- Biodiversity and **recovery** from perturbations, erosion, etc.
- Biodiversity as a **detective tool** of the **past**
  - Use to determine how long ago land was altered by human or natural activity

67

The Economics of Ecosystems & Biodiversity

Why valuation makes sense

❑ Existing market signals often lack appropriate consideration of the value of, the damage to, and incentives for, the sustainable use of biodiversity and ecosystem services

Understanding the value of ecosystem services can help to:

❑**Generate** better information about the 'value' of nature's services
❑**Identify** 'true' costs of business as usual
❑**Improve** decision making when tradeoffs are necessary and useful information is lacking
❑**Provide** a basis for policy formation and analysis
❑**Set** incentives and regulating use

TEEB Training

68

Recognize, Demonstrate, Capture

❑ TEEB follows a three-tiered approach towards ecosystem valuation by ***recognizing, demonstrating*** and ***capturing*** value.

❑ This approach helps to make nature more economically visible and ultimately influence key actors to change their decisions and behaviors

http://www.teebweb.org/

69

Suggested reading

Elmqvist et al., TEEB (2010). Ch2: Biodiversity, Ecosystems and Ecosystem Services [NB: the entire The Economics of Ecosystems and Biodiversity Foundation report can be downloaded from www.teebweb.org]

Luck, G.W. et al. (2009). Quantifying the contribution of organisms to the provision of ecosystem services. Bioscience, 59(3): 223-235.

Mace, G.M., Norris, K. & Fitter, A.H. (2012). Biodiversity and ecosystem services: a multi-layered relationship. Trends in Ecology and Evolution 27(1): 19-26.

Hooper et al., (2005) Ecological Monographs
http://www.esajournals.org/doi/abs/10.1890/04-0922

http://www.openness-project.eu/library/reference-book/sp-link-between-biodiversity-and-ecosystem-services

70