BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION

Course Instructor:

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Course Objectives

This course is intended to help the student:

1. Understand the basic concepts of biological diversity, including its definition, organization, distribution, importance, and measurement.
2. Appreciate the changes in global biodiversity and their driving factors, with special reference to the tropical rainforest
3. Become familiar with biodiversity conservation strategies and some global initiatives.

Assessment and Grading

- Continuous assessment – 30%
  - Mid-semester examinations (20%)
  - Quizzes (10%).
- Seminars and end-of-semester examination – 70%.
  - Seminars (20%)
  - End-of-semester examination (50%)

Seminars

- Students will be randomly assigned to groups.
- Similarly, seminar topics will be randomly assigned to each group.
- A minimum of two weeks will be given to each group to research the topic and prepare a 15-minute PowerPoint presentation.
- A written report (10-15 pages, double line spacing) will be turned in at the end of all the presentations.

Seminar Groups


GV501V


A visit to CRIG and PGRIG


Bunso Arboretum


GIJ
A Specialised University in Communications
CRIG, Tafo

Larabanga mosque


MOLE NATIONAL PARK


AS 7846 G
GH


Kintampo Waterfall


Kintampo Waterfall

Schedule of Lectures, Seminars, Examinations

Date	Week	Lecture	Topic
May 15, M	1	1	**Course Introduction** **Basic Concepts of Biodiversity** *Definition, current status, organization, distribution*
May 17, W	1	2	**The Value of Biodiversity**
May 22, M	2	3	**Measurement of Biodiversity** *Calculating alpha diversity using Excel and EstimateS* *Assignment 1*
May 24, W	2	4	**Biodiversity Changes and their Drivers** Documentary: Decade on Biodiversity *Global trends in biodiversity changes and their dimensions, Drivers of biodiversity change*
May 29, M	3	-	*Reading assignment 1: Mora et al. (2011). How many species are there on Earth and in the Oceans?*
May 31, W	3	-	*Reading Assignment 2: Diaz et al. (2019).* Pervasive human-driven life on Earth points to the need for transformative change. *Assignment #1 due*
Jun 5, M	4	5	**Natural Resource Consumption and Biodiversity Loss 1** *Types of resources; global resource consumption patterns* Quiz 1 (covers lectures on Biodiversity)

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Schedule of Lectures, Seminars, Examinations

Date	Week	Lecture	Topic
Jun 7, W	4	6	**Natural Resource Consumption and Biodiversity Loss 2** *Relationship of natural resources consumption to biodiversity and ecosystem services; pathways to sustainable consumption*
Jun 12, M	5	7	**Global Conservation Initiatives** *Aichi's Biodiversity Targets* *Documentary: Progress towards Aichi's Targets* *Formation of Seminar groups*
Jun 14, W	5	8	**Tropical Ecosystems of West Africa** Documentary: Tropical Rainforests Quiz 2 (Covers Lecture on natural resources)
Jun 19, M	6	9	**Vegetation Types of Ghana** Notes on Oral Presentations
Jun 21, W	6	10	**Case Studies: Environmental and Social Consequences of Economic Development and Conservation in Tropical Climate**

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Schedule of Lectures, Seminars, Examinations

Date	Week	Lecture	Topic
Jun 26-30	7	-	Mid Semester
Jul 3, M	8	11	**Conservation Principles and Strategies** *Definition, principles and methods of conservation*
Jul 5, W	8	12	Oral Presentations Series 1: Groups 1-4
Jul 10, M	9	13	**Ecological aspects of development** Ecotourism Coastal zone tourism Tourism conservation
Jul 12, W	9	-	Oral Presentations Series 2: Groups 5-8
Jul 17, M	10	-	Oral Presentations Series 3: Groups 9-12
Jul 19, W	10		Oral Presentations Series 4: Groups 13-16
Jul 24, M	11	-	Oral Presentations Series 5: Groups 17-20
Jul 26, W	11		Oral Presentations Series 6: Groups 21-24
Jul 31-Aug 4	12		Revision
Aug 7 – Aug 25	13-15		End of Semester Examinations

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General Etiquette

- Lateness will not be entertained.
- The University frowns upon all forms of academic dishonesty including plagiarism, impersonation, and cheating during exams.
- Mobile phones must stay switched off or in silent mode during class.
- Failure to turn in assignments on time will lead to deduction of points.
- Regular attendance and participation in class activities are strongly encouraged.

Course Evaluation

- Students will have the chance to evaluate the course and the instructor.
- Evaluation period: ***TBD***

Recommended Books/Readings

- Secretariat of the Convention on Biological Diversity. 2020. Global Biodiversity Outlook 5. Montreal.
- Diaz et al. 2019. Pervasive human-driven life on Earth points to the need for transformative change. Science 366, eaax3100.
- Pereira et al. 2012. Global Biodiversity Change: the bad, the good and the unknown. Annu. Rev. Environ. Resour. 37:25-50.
- Sodhi, N. S. and Ehrlich, P. R. 2010. Conservation Biology for All. Oxford University Press, UK.
- Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Biodiversity synthesis*. World Resources Institute, Washington DC.
- Sala et al. 2000. Global biodiversity scenarios for the year 2100. *Science* 287:1170-1174.

Unit 1: Basic Concepts of Biodiversity

"The earth will retain its most striking feature only if humans have the prescience to do so" - David Tilman (2000)

Learning Outcomes

By the end of this unit, students would be able to:

- define biodiversity and state how they are organized in nature
- explain the value of biodiversity
- describe the geographic distribution of biodiversity and explain why it is concentrated at the tropics.
- State the three levels at which biodiversity is measured

What is Biodiversity?

Also known as biological diversity, it refers to the ***variety of life***, in all of its manifestations.

Current biodiversity is the result of billions of years of evolution, shaped by natural processes and, increasingly by the influence of humans.

It forms the ***web of life***, of which humans are an integral part and upon which we so fully depend .

What is Biodiversity?

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) signed at Rio De Janeiro (Brazil) in 1992 by 154 countries defines biodiversity as:

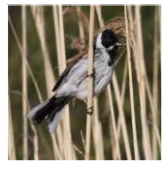
"the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems."

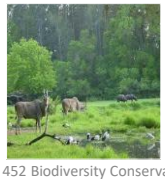
Biodiversity exists at three levels of organization:

- Genetic diversity
- Species diversity
- Habitat/Ecosystem diversity.

Genes

Species

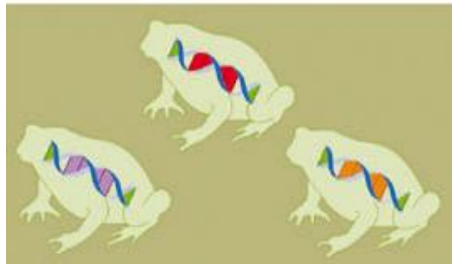




Ecosystems

Genetic diversity

- Variation in the genetic make-up among individuals of a given species.
- E.g. varieties of crop plants; breeds of livestock; social groups of honeybees.
- The total number of genes or the complete set of unique alleles in a species is known as the **gene pool**.



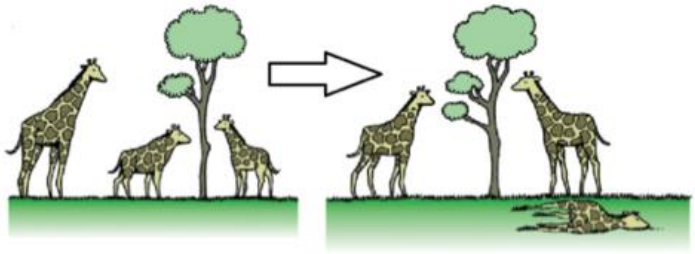
Honeybee colony

Genetic diversity

- A large gene pool indicates extensive genetic diversity.
  - Enables populations to adapt to changing climates; avoid inbreeding and disease epidemics.
- Raw material for evolution and adaptation.
- Measured in terms of allelic diversity, gene diversity or nucleotide differences.
- The most basic measure is the genome size—the amount of DNA in one copy of a species' chromosomes (or haploid nuclear DNA content). Also known as C-value.

Genetic diversity

- Can be measured at many levels including populations, community and biome



- Low genetic diversity leads to reduced biological fitness and increased chance of extinction.

Species diversity

The variety of different species that exist on earth and the relationship of different groups of species to each other.

Species diversity

- Typically, the focus of biodiversity research and conservation effects.

Species diversity

Species-based approach vs. ecosystem approach to conservation.

- *What are the strengths and weaknesses of species-based conservation approaches. How do these approaches compare to the ecosystem approach?*
  - *Strength: species are the unit of evolution; they are easily identifiable and conceptualized.*
  - *Weakness: Ecosystem approach is more holistic and takes into account the interdependence among different organisms, and their environment.*

Ecosystem diversity

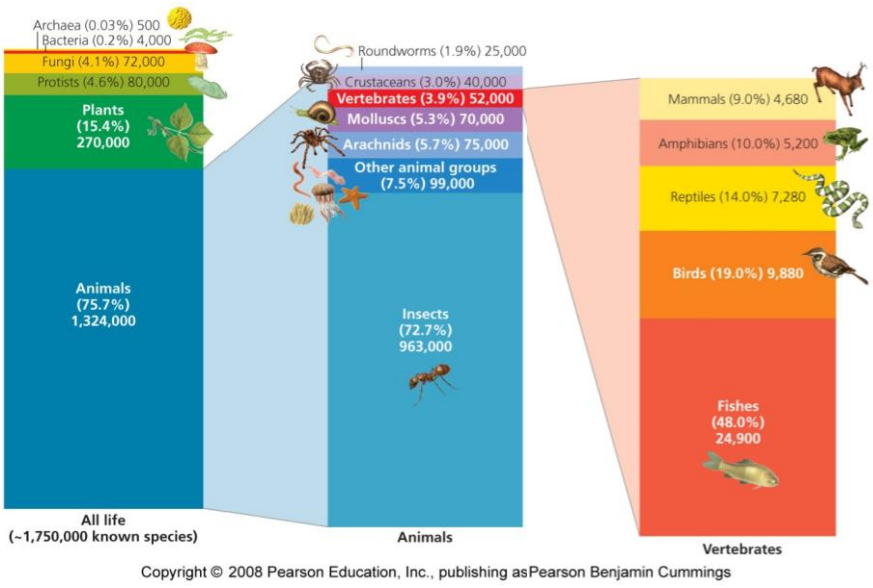
- Diversity above the species level.
- Different biological communities and their associated physical environment.
  - Niches
  - Community diversity
  - Habitat diversity
  - Landscape diversity

Ecosystem diversity

Arguably the least understood component of biodiversity

- Complexity of the interactions.
- Difficult to distinguish without recourse to some arbitrary rules.
- Some (e.g., ecosystems, ecoregions, biomes) have both biotic and abiotic components though biodiversity is defined as the variety of life.

Distribution of Global Biodiversity



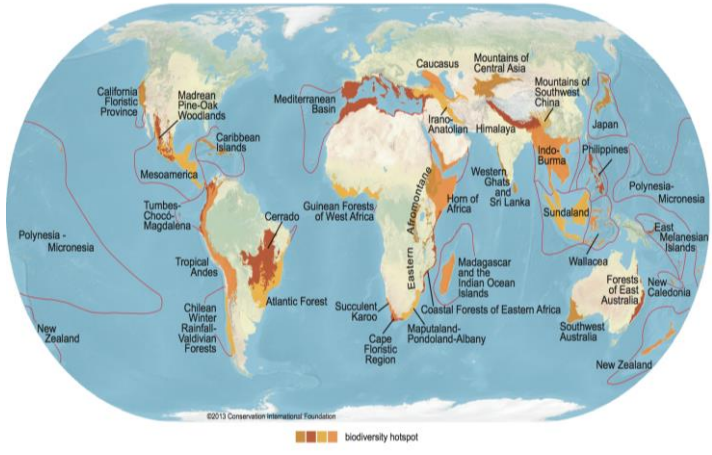
1.7—2.0 million species described by scientists.

Estimates suggest 8.6—100 million species.

Around 20,000 new species are described each year

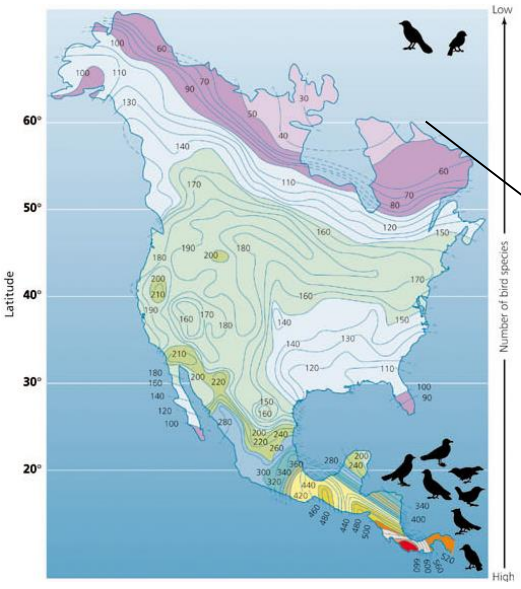
Where is the biodiversity?

- Everywhere
  - Every continent and habitat has unique life forms.
- Concentrated in the tropics; coral reefs
  - E.g. 10 ha of forest in Amazonian Brazil might have 300+ tree species; about 30 in Europe or US.
- Biodiversity Hotspots:
  - Regions with high biodiversity and greatest threat.
  - Not the same as wilderness area.



34 Biodiversity hotspots identified globally by Conservation International

Latitudinal gradient in biodiversity distribution

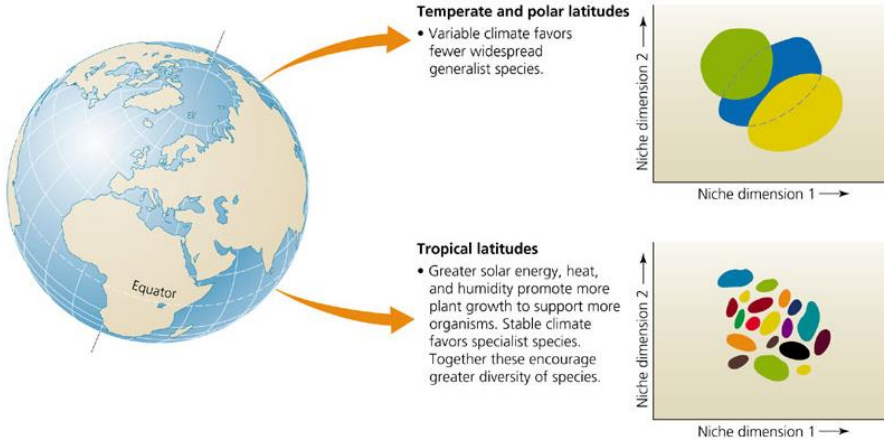


Species richness increases toward the equator.

30–100 bird species in large area of the Arctic.

500–700 bird species in small area of the tropics

Latitudinal Gradient in Biodiversity Distribution Explained



- Tropical climates encourage specialist species that can pack tightly in a community

Pearson Education Inc.,2005

What is the Value of Biodiversity?

Biodiversity is the living fabric of our planet and the foundation of human life and prosperity

– Antonio Guterres (UN Secretary General)

Value of Biodiversity

- There are both intrinsic and utilitarian values for preserving biodiversity.

- These values can also be classified as:
  - Economic/Instrumental
  - Ecological
  - Ethical/Moral

Economic/Instrumental Value

Agricultural/Genetic resources

- Many species not now commonly used for food could be.
- Genetic diversity within crop species and their relatives enhance our agriculture and provide insurance against losses of prevalent strains of staple crops.

Pearson Education Inc., 2005

Medicine

Medicines and Biodiversity: Natural sources of pharmaceuticals		
Plant	Drug	Medical application
Pineapple (*Ananas comosus*)	Bromelain	Controls tissue inflammation
Autumn crocus (*Colchicum autumnale*)	Colchicine	Anticancer agent
Yellow cinchona (*Cinchona ledgeriana*)	Quinine	Antimalarial
Common thyme (*Thymus vulgaris*)	Thymol	Cures fungal infection
Pacific yew (*Taxus brevifolia*)	Taxol	Anticancer (esp. ovarian cancer)
Velvet bean (*Mucuna deeringiana*)	L-Dopa	Parkinson's disease suppressant
Common foxglove (*Digitalis purpurea*)	Digitoxin	Cardiac stimulant

- Ten of our top 25 drugs come directly from wild plants; the rest were developed because of studying the chemistry of wild species.
- Many species can provide novel medicines; we don't want to drive these extinct without ever discovering their uses.

Pearson Education Inc., 2005

Economic Argument for Conserving Biodiversity

Now widely used by conservation biologists

- Underlying cause of biodiversity loss is economic; solution must incorporate economic principles.
- Governments and Corporate officials may be convinced to protect biodiversity when there is an economic incentive to do so.
- Perhaps, governments and corporations will act when the loss of biodiversity is perceived to cost money.
- What is the challenge of using the economic argument for preservation of biodiversity?

Kakum National Park, Ghana

Tourists pay good money to see wildlife, novel natural communities, and protected ecosystems.

Can a price value be put on biodiversity?

- It is a great challenge to assign a price value to biodiversity.
- **The tragedy of the commons**—a situation in which the value of the common property resources is lost to all society (Hardin 1968, 1985).
  - most natural resources such as clean air, clean water, soil quality, **rare species** and even scenic beauty, are considered to be **common property resources**, collectively owned by society at large or owned by no one, with open access to everyone. These properties are rarely assigned a monetary value. People, industries, and governments use and damage these resources without paying more than a minimal cost, or sometimes paying nothing at all.

Ecological Value of Biodiversity

- Biodiversity provides many non-economic benefits (***goods and services that sustain our lives)*** called ***ecosystem services***

"Goods and Services" provided by ecosystems include:

- Provision of food, fuel and fibre
- Provision of shelter and building materials
- Purification of air and water
- Detoxification and decomposition of wastes
- Stabilization and moderation of the Earth's climate
- Moderation of floods, droughts, temperature extremes and the forces of wind
- Generation and renewal of soil fertility, including nutrient cycling
- Pollination of plants, including many crops
- Control of pests and diseases
- Maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines, and other products
- Cultural and aesthetic benefits
- Ability to adapt to change

CBD, 2000

Categories of Ecosystem Services

Provisioning services

Supporting services

Ecosystem services

PROVISIONING SERVICES
Food, fiber, and fuel
Genetic resources
Biochemicals
Fresh water

CULTURAL SERVICES
Spiritual and religious values
Knowledge system
Education and inspiration
Recreation and aesthetic values
Sense of place

SUPPORTING SERVICES
Primary production
Provision of habitat
Nutrient cycling
Soil formation and retention
Production of atmospheric oxygen
Water cycling

REGULATING SERVICES
Invasion resistance
Herbivory
Pollination
Seed dispersal
Climate regulation
Pest regulation
Disease regulation
Natural hazard protection
Erosion regulation
Water purification

Cultural services

Regulating services

How important are these services to human wellbeing and survival?

Ecological Argument for Biodiversity Conservation

- A relatively new concept; useful in communicating with policymakers, businesses and citizens.
  - Connects biodiversity components with human well-being.
- Aesthetic, recreation, and educational and scientific values
- Losing species and habitats reduces the Earth's capacity to support human life.
  - We do not know the tipping point

Kakum National Park, Ghana

Honeybee: a keystone species

Ethical Values of Biodiversity

- Humans have the moral duty to protect species
  - Based on their intrinsic values, unrelated to human needs.
  - We are just one of the species on the planet, with no right to destroy others.
- There is only one planet known to have life.
  - We have responsibility to future generations to keep the earth in good condition.

Ethical Values

- Ethical arguments provide perhaps the most convincing reasons for preserving biodiversity
  - Grounded in the value systems of most religions and cultures.
  - Protect species with no obvious benefit to people.

How can we measure biodiversity?

MEASURING BIODIVERSITY

- There is no single measure of biodiversity.
- Analyses often framed in terms of particular elements or groups of elements, most commonly species diversity.
- Species diversity can be measured at three scales:
  - Alpha (α) diversity
  - Beta (β) diversity
  - Gamma (γ) diversity

Alpha Diversity

- Diversity of species within an ecological community.
- Usually described as a measure of two attributes
  - *Species richness*; the number of species in a community. i.e., number per unit area.
  - *Species evenness*; the relative abundance of different species within a community; measures equitability.

Sampling unit

Species diversity

S = species no.

H = takes into account number of species and abundance of each

Woodland A

Which community is more stable if one species is lost? Which can survive?

Woodland B

Gaston, 2010

Alpha Diversity

SPECIES	SITE A	SITE B
Common yellowthroat	8.24	1.21
Field sparrow	2.94	2.84
Dickcissel	1.18	2.23
Red-winged blackbird	0.29	0.81
Brown-headed cowbird	2.06	1.82
Eastern kingbird	-	1.60
Mourning dove	1.18	0.61
Grasshopper sparrow	-	4.48

Abundance (individuals/10ha) of avian species from two tall grass prairie sites

Which of the two sites is more diverse?

Alpha Diversity Indices

- Several indices exist for measuring alpha diversity.
- The most popular is the Shannon index, H^1

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where p^i is the proportion of the total community abundance represented by the *i*th species, ln(p_i) is the natural log of p_i and S is the total number of species.

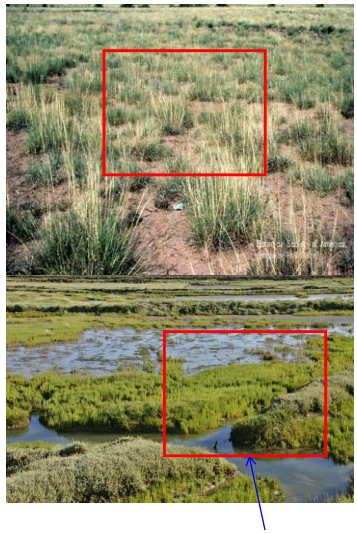
- Shannon evenness index (E) is calculted as
  $E = H/H_{max}$. H_{max} is the maximum possible value of H which is equivalent to ln S. Thus $E = H/lnS$

Assignment #1

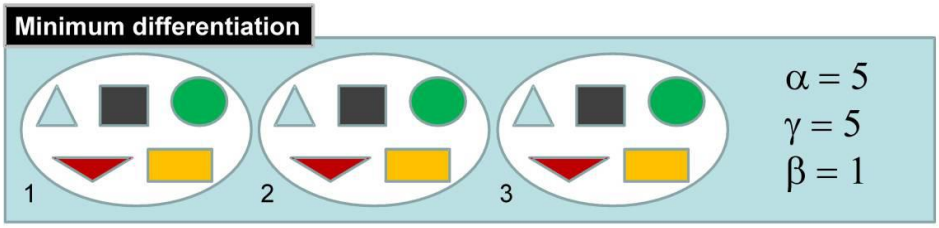
- Identify and write short notes on **any other four** alpha diversity indices apart from Shannon index.
- Due date: 31st May, 2023
- Maximum two pages. Double line spacing, Times New Roman, Font 12.
- Submit: Hardcopies.

Beta diversity

- Ratio between gamma (regional) diversity and alpha (local) diversity.
- Provides the first approximation of area or regional diversity. i.e., the number of different communities in a region.
- First introduced by R. H. Whittaker in 1960.

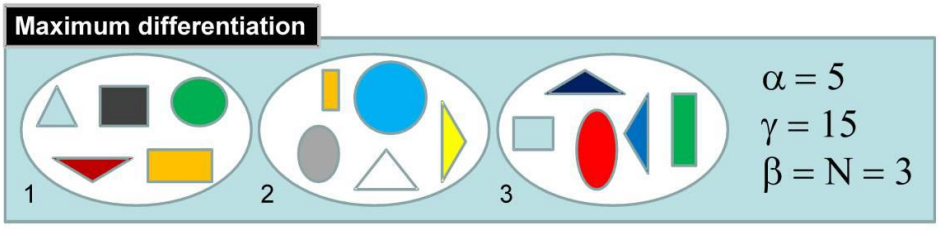


Beta diversity measure



- Mean local species richness (alpha diversity) equal regional species richness (gamma diversity).
- Beta diversity = gamma diversity/alpha diversity = unity.
- This means there is effectively only one distinct compositional unit (i.e., only one community).

Beta diversity measure

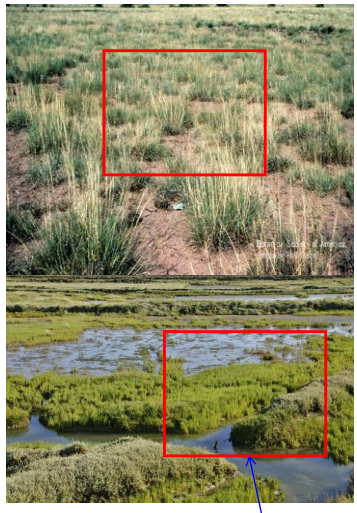


- When local assemblages are all completely different (maximum differentiation), gamma diversity equals the multiplication of alpha diversity by the number of sites (N).
- This means that there are N distinct compositional units or N different communities.

Beta diversity

Six main measures of b diversity

- Whittaker's measure b_W
- Cody's measure b_C
- Routledge's measure b_R
- Routledge's measure b_I
- Routledge's measure b_E
- Wilson & Shmida's measure b_T

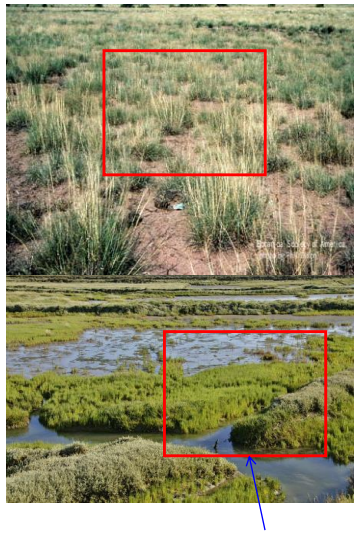


Best beta diversity measure?

Whittaker's diversity index is the best and the most commonly used:

$$(S/\alpha) - 1$$

where *S* is the number of species in the entire set of sites and α represents the average number of species per site, with sites standardized to a common size.



Beta Diversity

- Index value of zero (0) indicates a highly homogenous landscape with respect to a particular environmental gradient.

- Beta diversity gives insight into
  - Diversity of communities caused by gradients in the environment.
  - The relative sensitivity of species in different communities to changing environment.
  - Effects of environmental gradients; how species are gained or lost relative to other factors.

Gamma Diversity

- Diversity of species across larger landscapes.

- Product of alpha diversity of landscape's communities and *beta differentiation* among them.

  $\gamma = \alpha \times \beta$

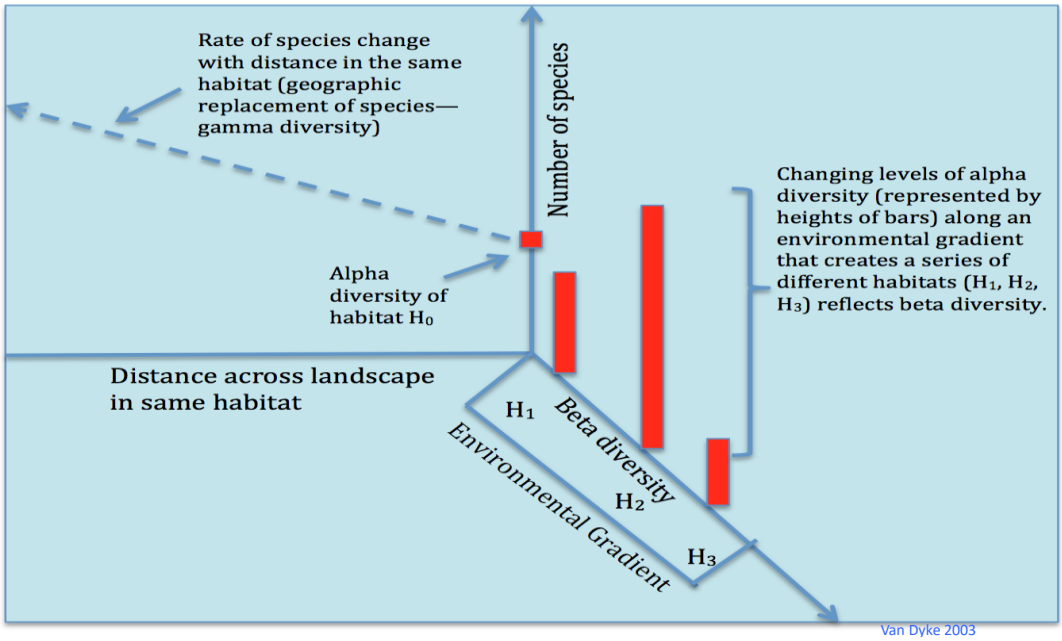
- Defined as the species turnover rate with distance between sites of similar habitats or with expanding geographic area.

- Independent of habitat, and is calculated as

  $dS/dD[(g + l)/2]$,

  which is the rate of change of species composition (S) with respect to distance. D is the distance over which species turn over occurs, and g and l are the respective rates of species gain and loss.

Biodiversity measurement -- summary



Van Dyke 2003

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Calculating Alpha and Beta diversity (Worked Examples)

- Calculations can be done simply using Microsoft Excel and other statistical software
- **EstimateS** developed by Robert Colwell
- Anne Chao's SpadeR (species prediction and diversity estimation integrated into R)