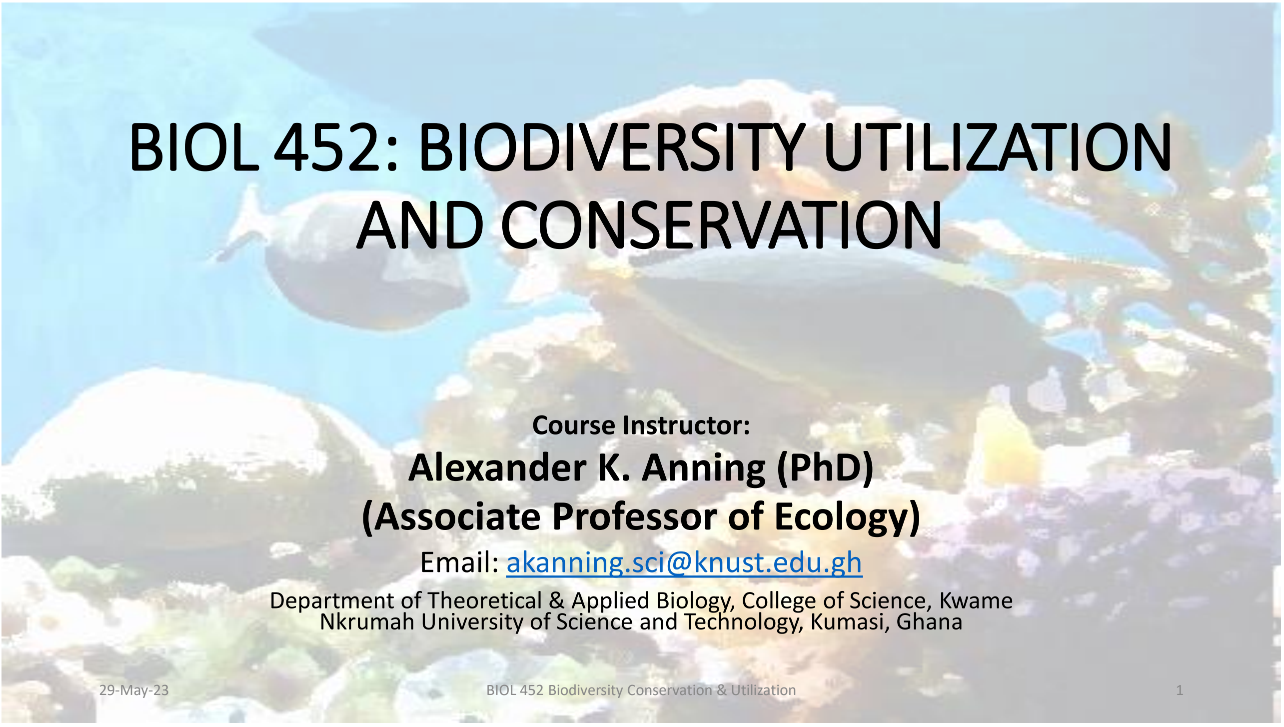


BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION

Course Instructor:

Alexander K. Anning (PhD)

(Associate Professor of Ecology)

Email: akanning.sci@knust.edu.gh

Department of Theoretical & Applied Biology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

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


FORESTRY COMMISSION
MOLE NATIONAL PARK
BY PARK AUTHORITIES


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)

19

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**

20

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

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?

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.

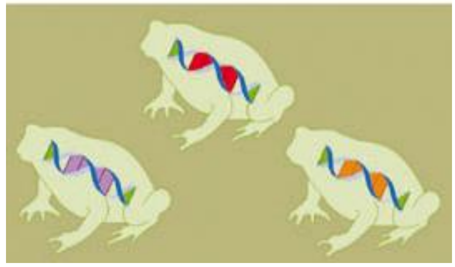
Genes

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**.



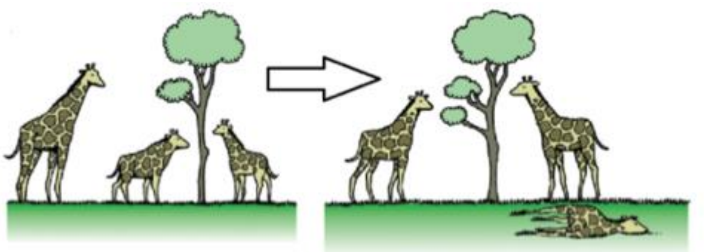
Honeybee colony

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

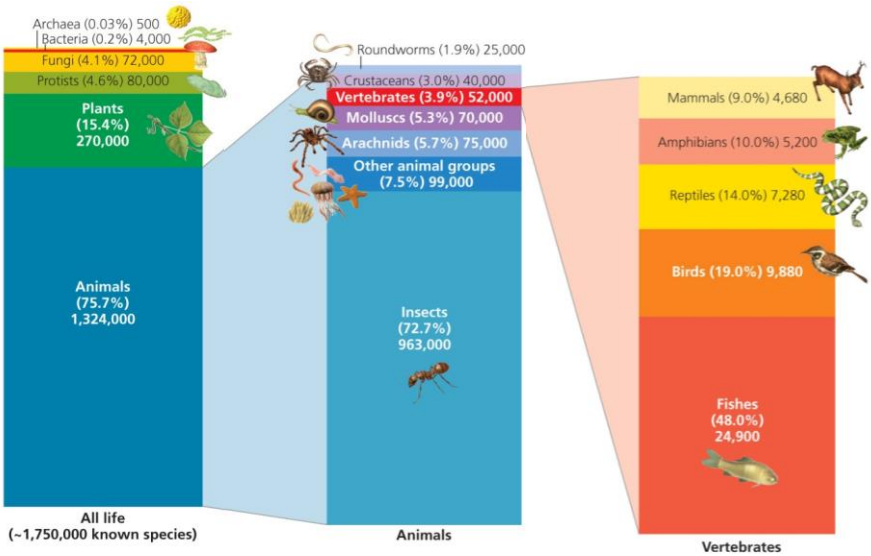
- Diversity above the species level.
- Different biological communities and their associated physical environment.
  - Niches
  - Community diversity
  - Habitat diversity
  - Landscape diversity

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



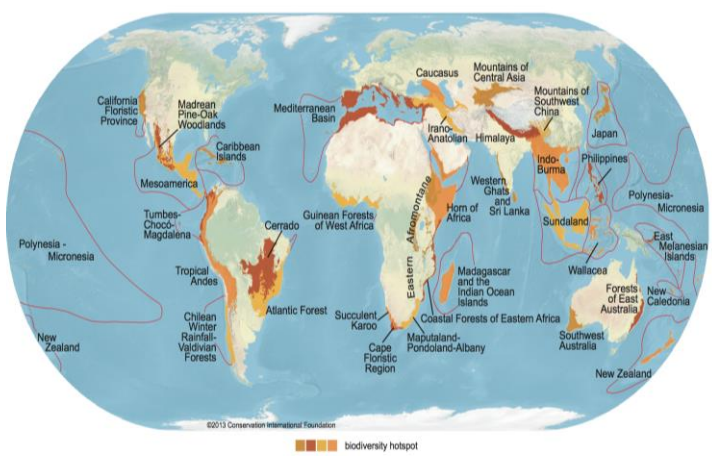
1.7—2.0 million species described by scientists.

Estimates suggest 8.6—100 million species.

Around 20,000 new species are described each year

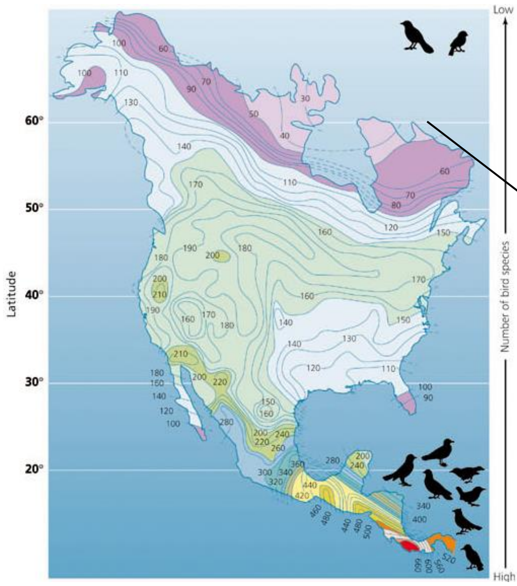
Where is the biodiversity?

- 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

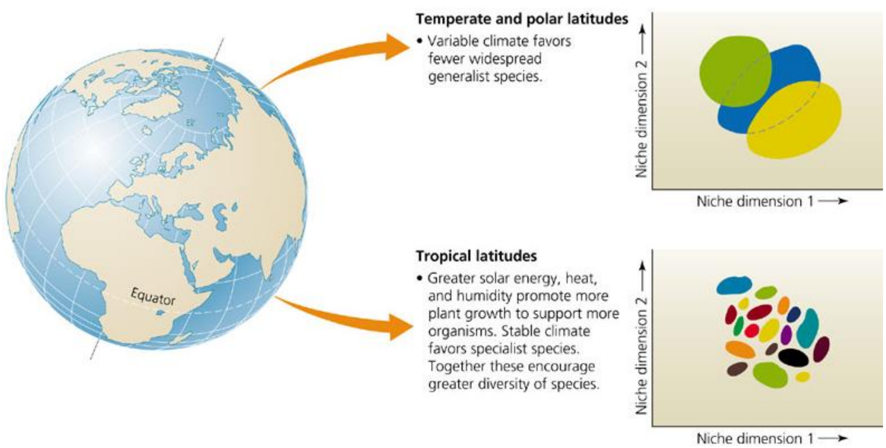


Species richness increases toward the equator.

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

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

Supporting 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?

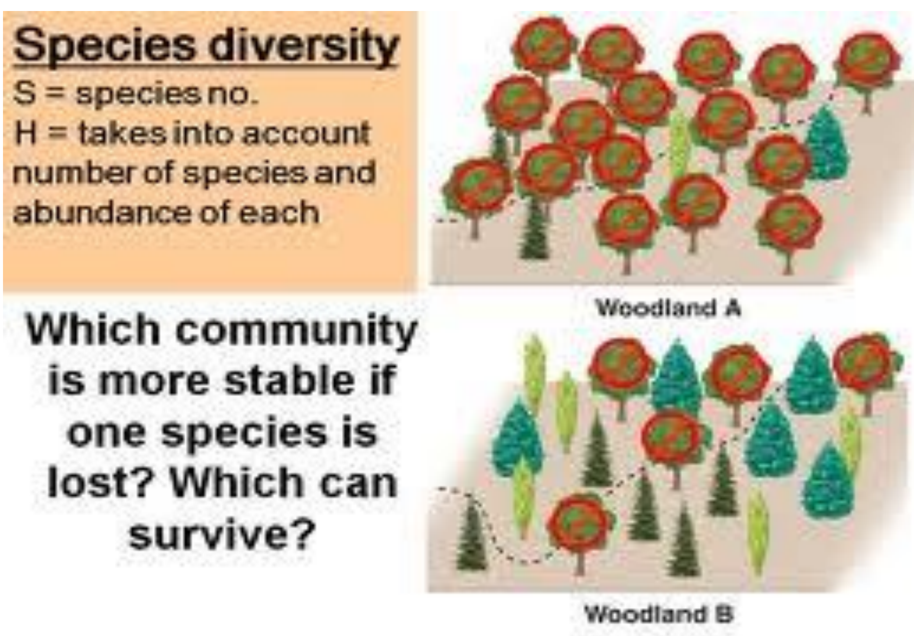
MEASURING BIODIVERSITY

- 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



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 ith species, $\ln(p_i)$ is the natural log of p_i and S is the total number of species.

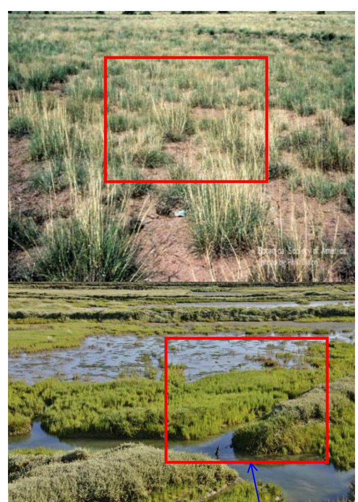
- Shannon evenness index (E) is calculted as
  $E = H/H_{max}$. H_{max} is the maximum possible value of H which is equivalent to $\ln S$. Thus $E = H/\ln S$

Assignment #1

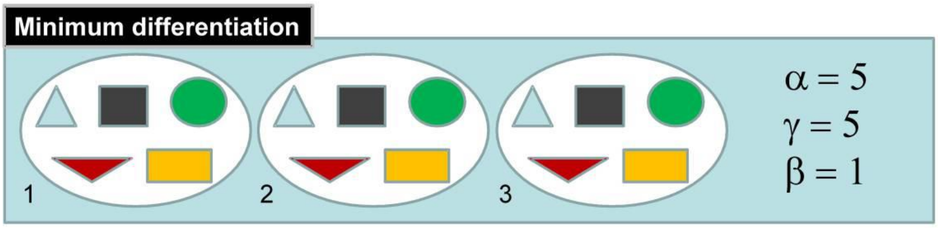
- Identify and write short notes on **any other four** alpha diversity indices apart from Shannon index.
- Due date: 31st May, 2023
- Maximum two pages. Double line spacing, Times New Roman, Font 12.
- Submit: Hardcopies.

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.

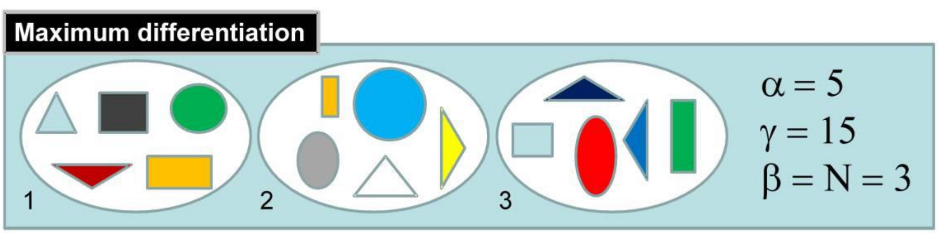


Beta diversity measure



- 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

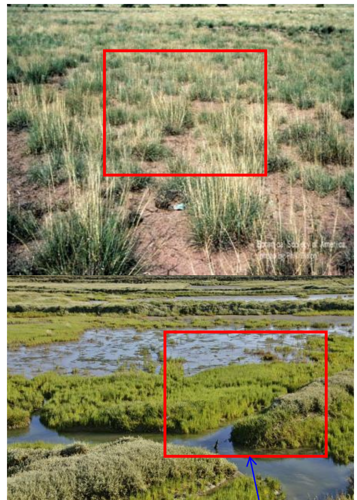


- When local assemblages are all completely different (maximum differentiation), gamma diversity equals the multiplication of alpha diversity by the number of sites (N).
- This means that there are N distinct compositional units or N different communities.

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



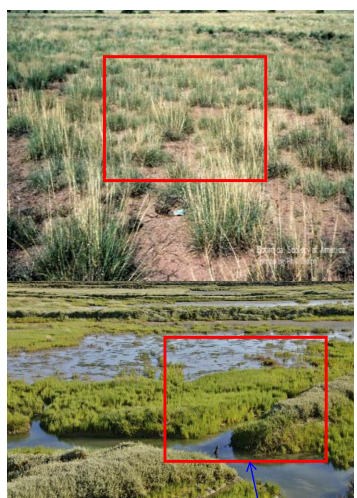
Sampling unit

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.



Sampling unit

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.

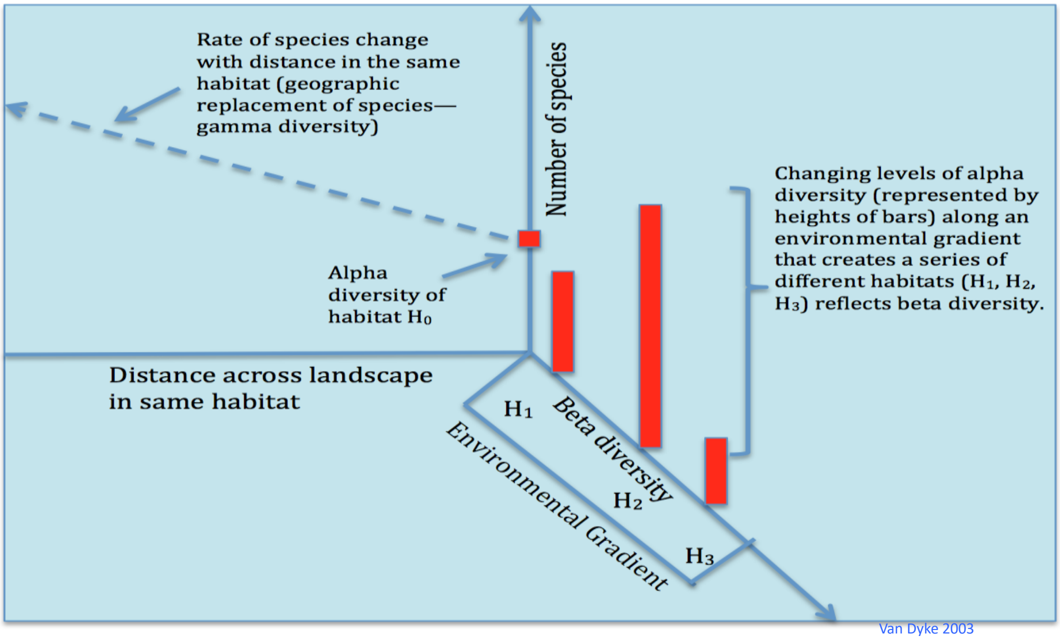
  $\boldsymbol{\gamma = \alpha \times \beta}$

- 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

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)

Biodiversity Changes and their Drivers

"Biodiversity and nature's contribution to people are our common heritage and humanity's most important life-supporting 'safety net'. But this safety net is stretched almost to the breaking point" – Prof. Sandra Diaz (Co-Chair, IPBES, 2019)

Learning Outcomes

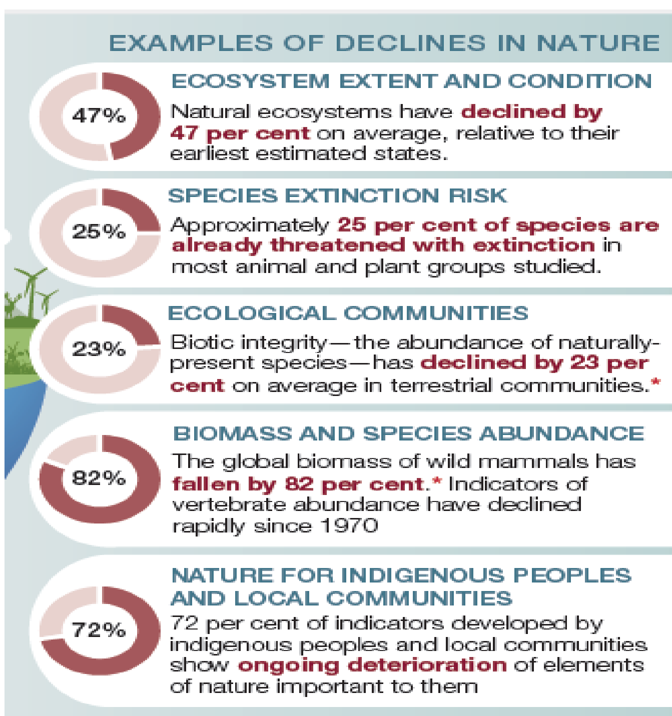
By the end of this unit, students will:

- Become aware of the changing global trends of biodiversity
- Appreciate the factors that are driving species into extinction
- Understand the varying patterns of human consumption of natural resource and their role in biodiversity loss

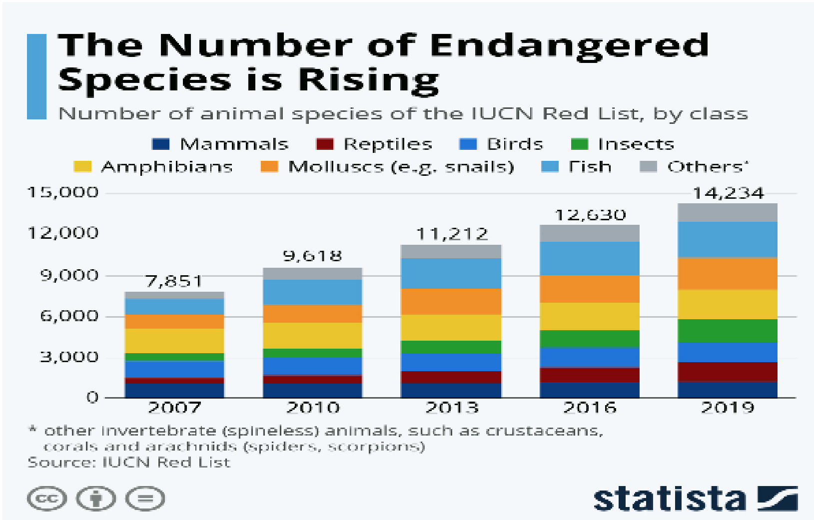
Trends in Global Biodiversity Change

- Biodiversity change is one of the most pressing environmental issues of our time; an important global change in its own right.
- Since 1970, biodiversity has declined at a rate unprecedented in human history.
- Pressures driving this decline are also intensifying.

IPBES (2019)



Global Biodiversity Change



Global trends in the capacity of nature to sustain contributions to good quality life (1970-2019; IPBES 2019)

Figure SPM 1 Global trends in the capacity of nature to sustain contributions to good quality of life from 1970 to the present, which show a decline for 14 of the 18 categories of nature's contributions to people analysed.

Trends in Global Biodiversity Change

- About 35-40% of the world's forest and natural free ice habitats have been converted to cropland and pasture
- Half of the world's large river systems have been affected by dams
- About 40% of the oceans have been affected by several drivers

Dimensions of Biodiversity Change

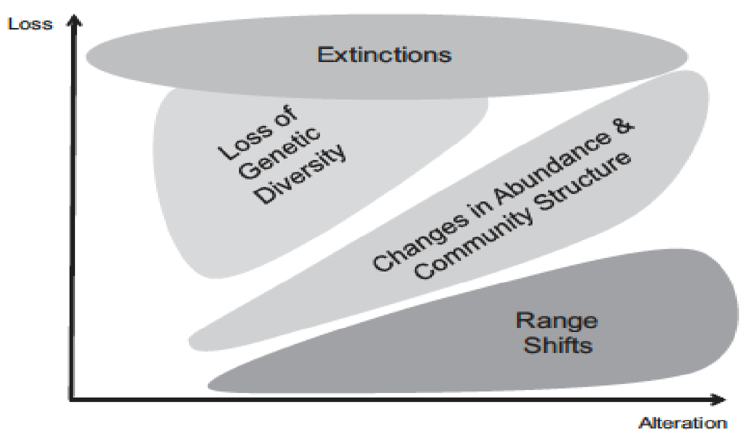


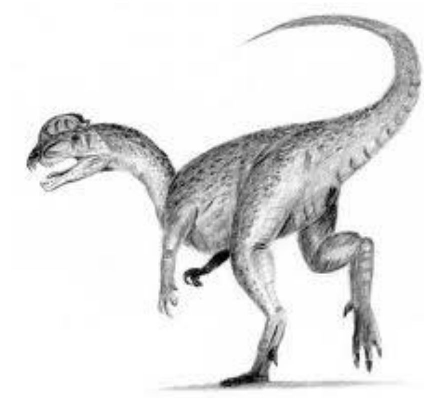
Figure 1

Conceptual diagram illustrating the intensity of loss and alterations associated with the different dimensions of biodiversity change: extinctions, loss of genetic diversity, changes in abundance and community structure, and range shifts.

Pereira et al. 2012

Extinction of Biodiversity

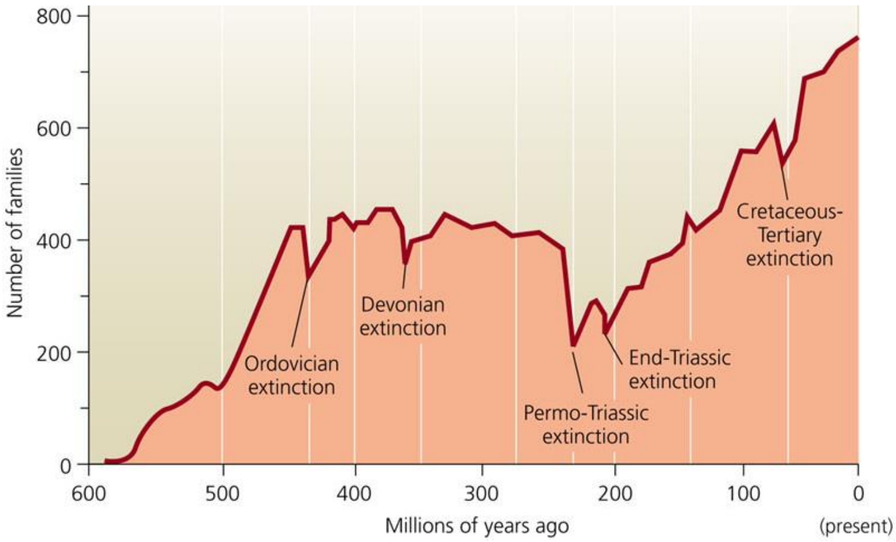
- Global biodiversity including the genetic resources is declining.
- The loss of biodiversity may take many forms but the most dramatic aspect is ***extinction***.
- A species is extinct when no member of the species remains alive anywhere in the world (global extinction).



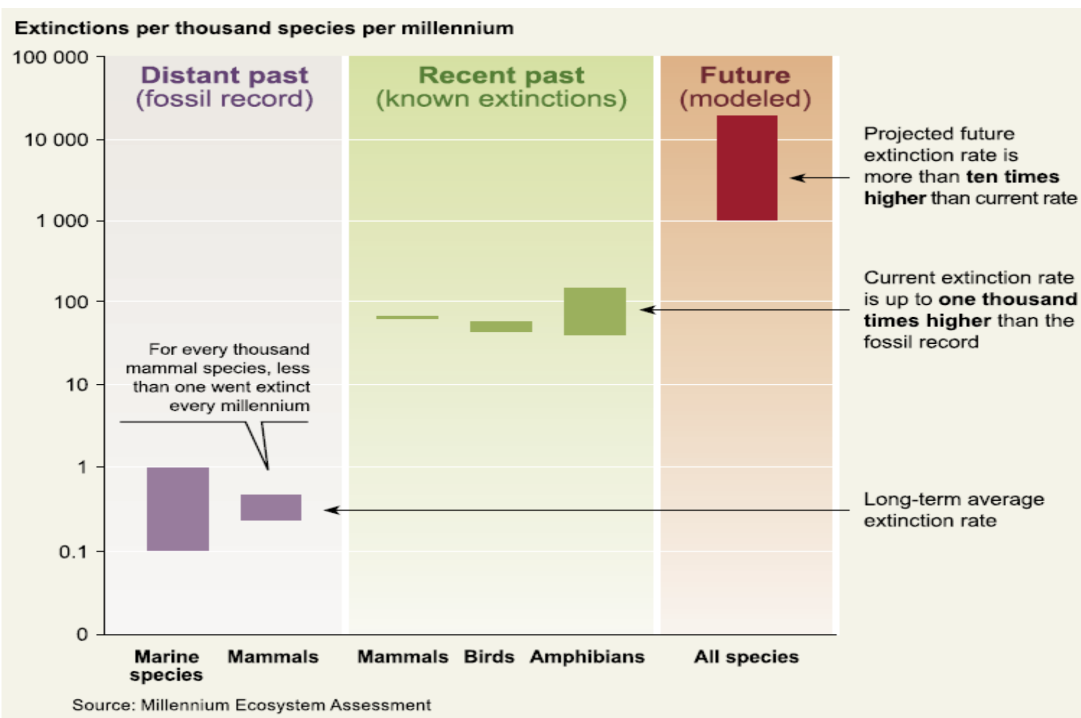
Extinction

- Extinction is a natural process, perhaps routine, from geological perspective.
- Background rate of extinction
  - On average, one species goes extinct naturally every 500-1000 years.
  - Approximately, 99% of all species that ever lived are now extinct.
- Occasionally, there has been episodes of mass extinction, an event in which a large percentage of all living species become extinct.

Mass extinctions



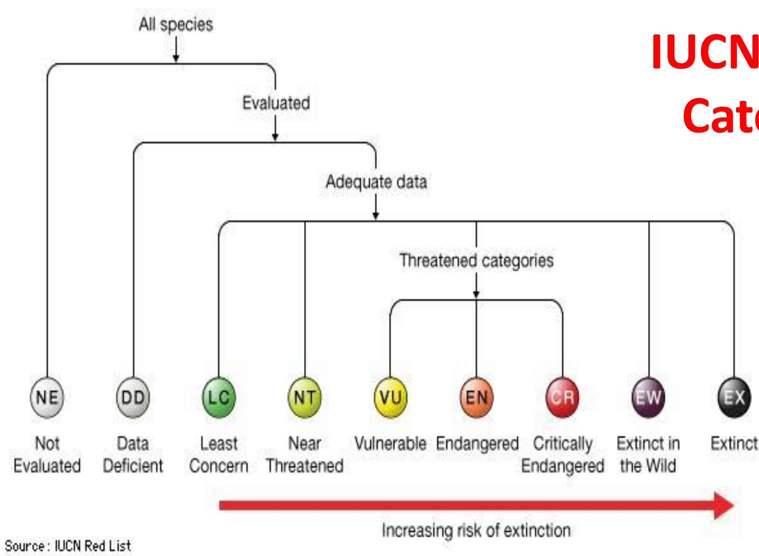
Earth has experienced five **mass extinction** events in which over half its species were wiped out suddenly.



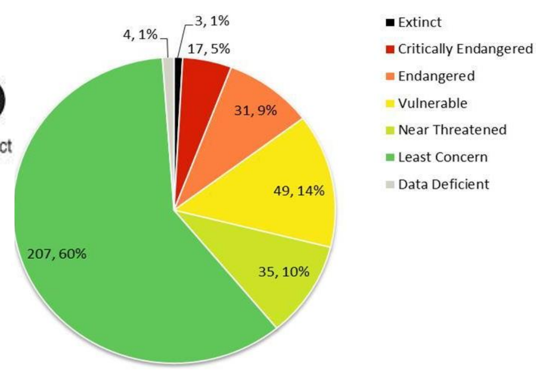
Today's mass extinction

- Currently, the earth is undergoing its sixth mass extinction—because of us.
  - Human have increased the rate and magnitude of extinction by 50-1000 times more than naturally expected.
  - 1,100 species are known to have gone extinct in the past 400 years.
- The **Red List**, from the IUCN, lists species that today are facing high risks of extinction.

IUCN Red List Categories



❖ 1,000,000 species threatened with extinction (IPBES, 2019)



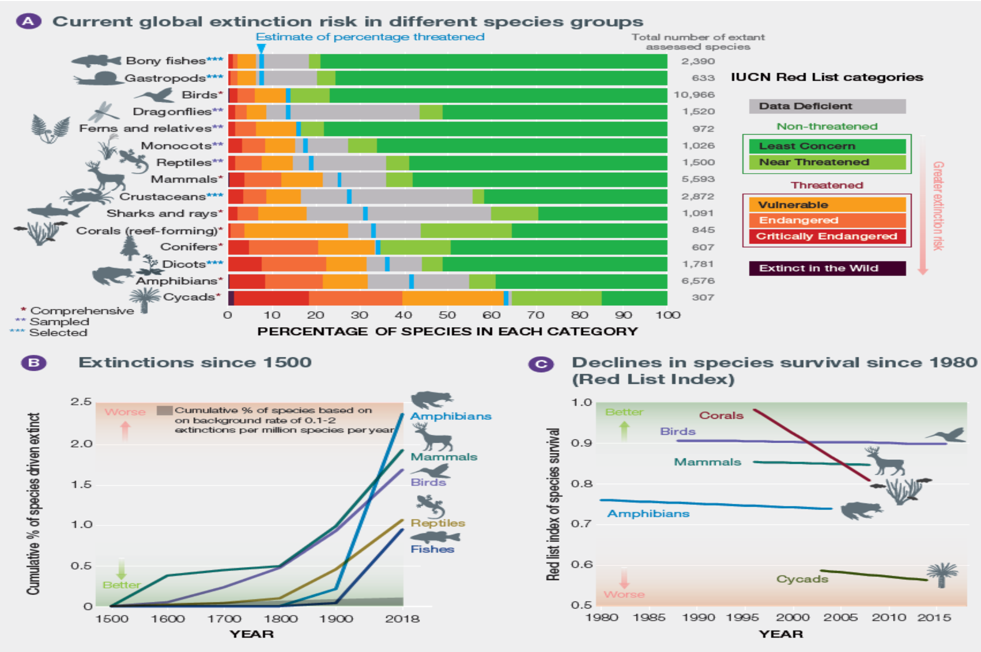
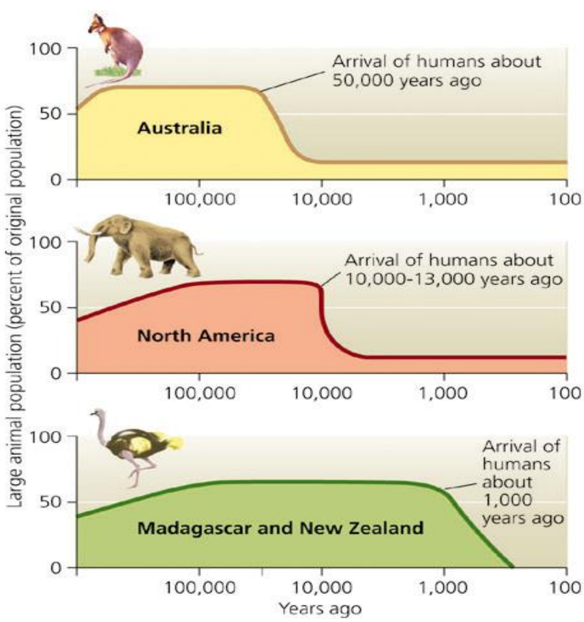


Figure SPM 3 A substantial proportion of assessed species are threatened with extinction and overall trends are deteriorating, with extinction rates increasing sharply in the past century.

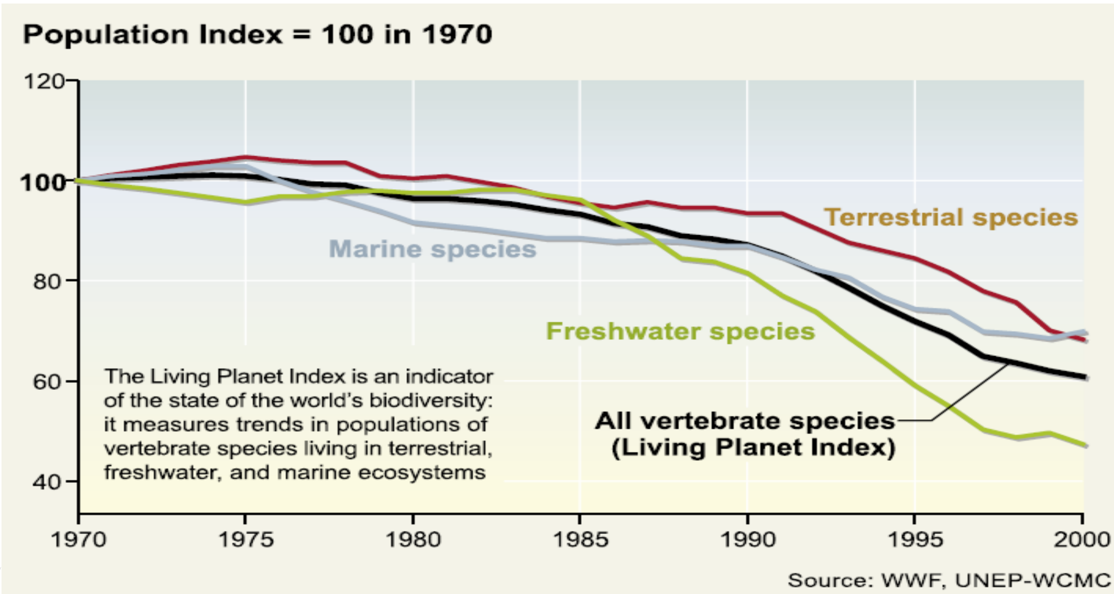
Today's mass extinction



Species of large mammals and birds plummeted with the arrival of humans, independently, on each of three continents—suggesting that human hunting was the cause.

Pearson Educational Inc., 2005

Today's Mass Extinction



What are the Main Direct and Indirect Drivers of Biodiversity Change?

Threats to Biodiversity

*"The worst thing that can happen during the 1980s is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. **The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats.** This is the folly that our descendants are least likely to forgive us."*

— E. O. Wilson, 1985

Direct and Indirect Drivers of Biodiversity Change

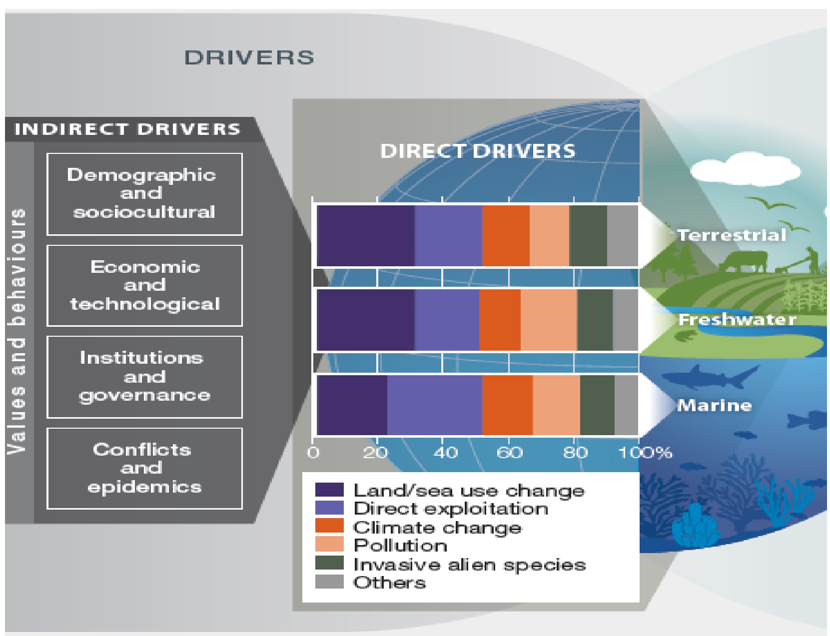


Figure 3. Main Direct Drivers

The cell color indicates the impact to date of each driver on biodiversity in each biome over the past 50–100 years. The arrows indicate the trend in the impact of the driver on biodiversity. Horizontal arrows indicate a continuation of the current level of impact; diagonal and vertical arrows indicate progressively increasing trends in impact. This Figure is based on expert opinion consistent with and based on the analysis of drivers of change in various chapters of the assessment report of the Condition and Trends Working Group. This Figure presents global impacts and trends that may be different from those in specific regions.

Drivers of Biodiversity Change in 2100?

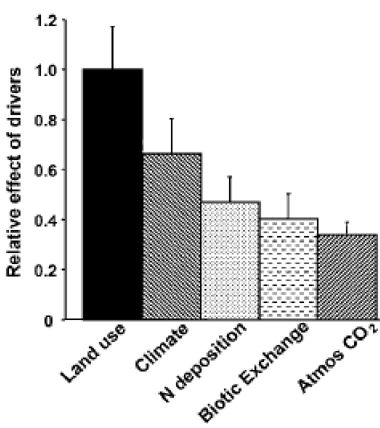


Fig. 1. Relative effect of major drivers of changes on biodiversity. Expected biodiversity change for each biome for the year 2100 was calculated as the product of the expected change in

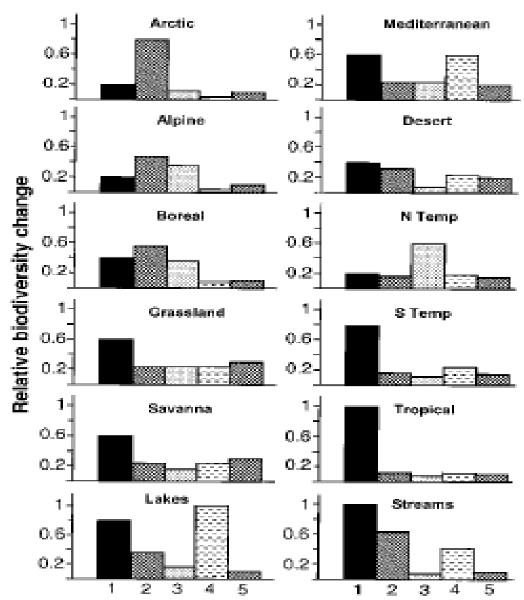
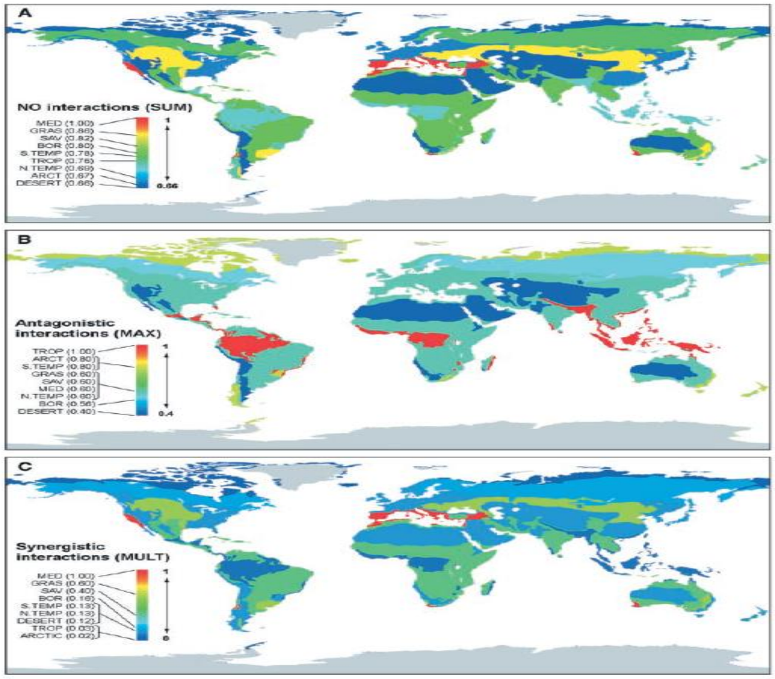


Fig. 2. Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of

Sala et al. 2000

Which ecosystems will be most affected in 2100?



Sala et al. 2000

Fig. 3. Maps of three scenarios of the expected change in biodiversity for the year 2100. **(A)** There are no interactions among drivers of biodiversity change; consequently, total change is calculated as the

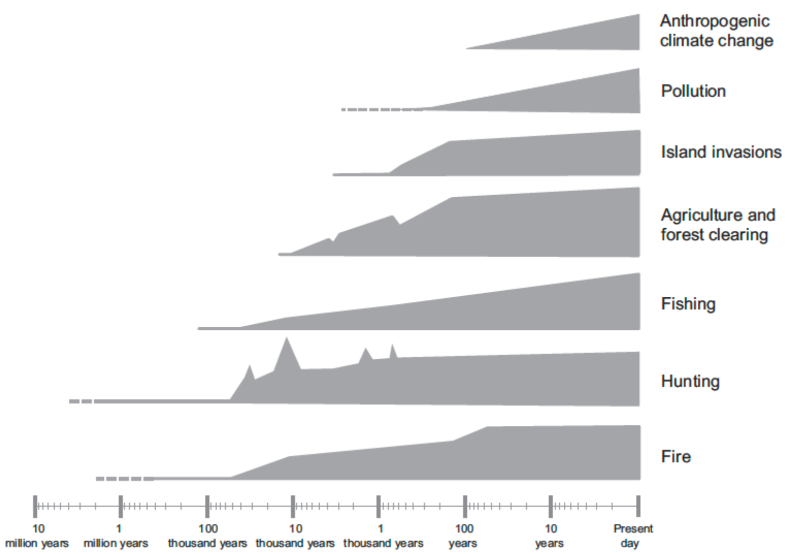


Figure 2

Qualitative representation of the temporal evolution of the main anthropogenic drivers of biodiversity change. References used for dating the pressure trend of each driver: fire (23, 24), hunting (28), fishing (160), agriculture and forest clearing (36, 40, 41), species invasions on islands (42), pollution (2), and anthropogenic climate change (138).

Pereira et al. 2012

Habitat Destruction

- Primary cause of biodiversity loss today.
- Results from expanding population growth and human activities.
  - Forest clearing
  - Agriculture
  - Urban development
  - Land use change, etc
- Limits resources for organisms or alters how they interact with other organisms.
- *Immediate* or *direct* impacts on ecosystems or biodiversity.

Habitat Destruction

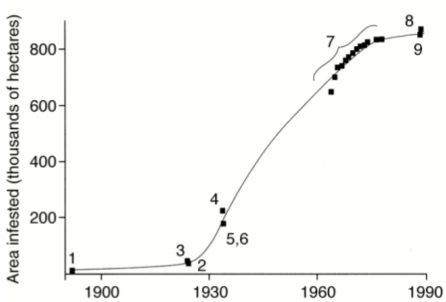
- Native species might have to relocate or they will die.
- Declining population of one species can affect an entire ecosystem—**keystone species**, for example.
- **Habitat fragmentation**: a closely related process to habitat destruction.
  - Separation of an ecosystem into smaller pieces of land.
  - Reduces the opportunities for individuals in one area to reproduce with those of another area (***reproductive barrier***).
  - Increases ***edge effect*** (different environment – abiotic conditions, that occur along the boundaries of an ecosystem.)
    - Renders species more vulnerable to predators and parasites
    - Not always a disadvantage; some species may find these conditions favourable.

Invasive Species

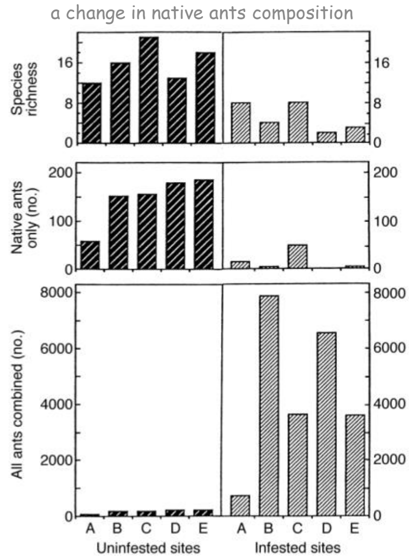
- Nonnative species intentionally or unintentionally introduced into a new habitat.
- Worldwide environmental problem.
  - Second major threat to native biota after habitat destruction.
  - Accounts for about 40% of extinction since 1750.
  - Control costs runs into billions of dollars.

Invasive Species

- Invader populations in new ranges have been accelerating with pronounced "lag" and "log" phases of spread.
- Usually outcompete the native species for resources.



Invasion of Brazilian ant in Texas causes a change in native ants composition



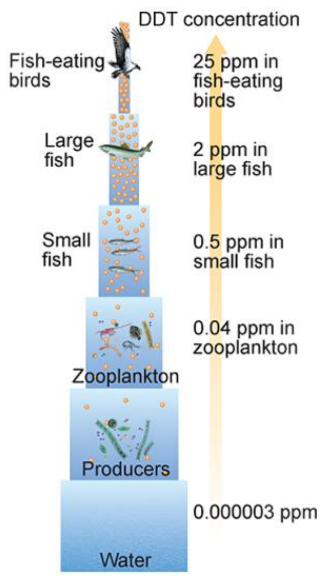
Mack *et al*. 2000

Pollution

- Air, water and land pollution
- Degrade the environment
- Threatens biodiversity and stability of ecosystems, globally.

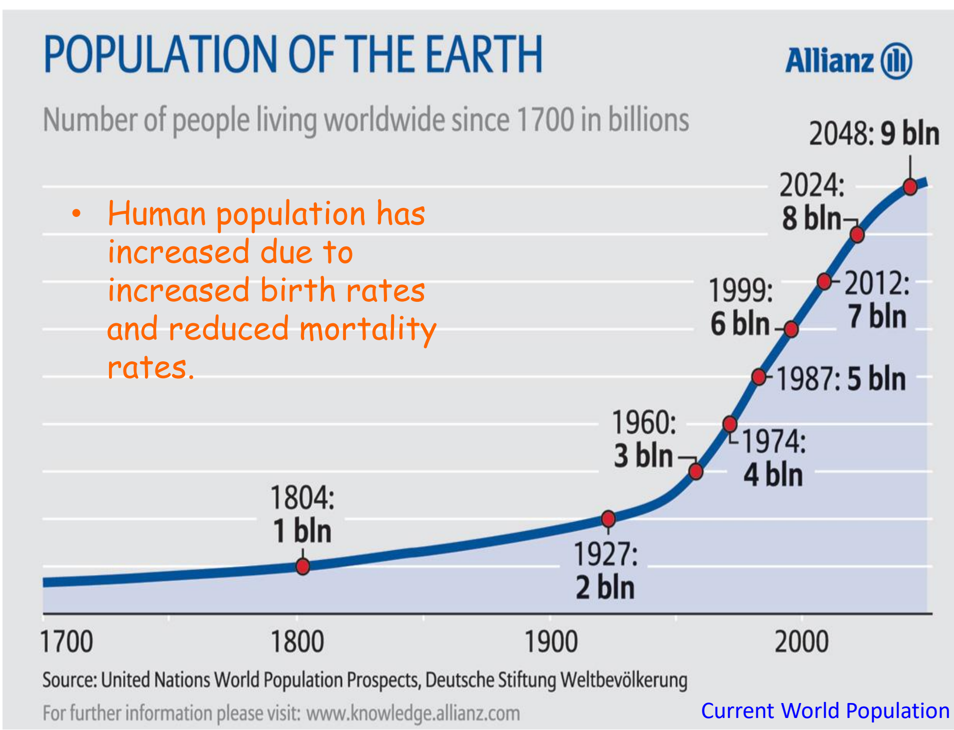
Pollution

- **Biological magnification**
  - Increasing concentration of toxic substances in organisms as trophic levels increase.
  - E.g., pesticides such as DDT.
- **Acid rain**
  - Sulphur and nitrogen compounds react with water and other substances in air to form sulphuric acid and nitric acid.
  - Precipitation of these acid removes calcium, potassium, and other nutrients from the soil, depriving plants of nutrients.
  - Damages plant tissue and slows growth.
  - May cause fish and other organisms to die, if concentrations are high.



Pollution

- **Eutrophication**
  - Occurs when fertilizers, animal wastes, sewage, or other substances rich in nitrogen and phosphorus flow into water ways causing extensive algal growth.
  - Algae use up the oxygen supply during their rapid growth, and after their deaths during the decaying process.
  - Eutrophication is a natural process, but human activies have accelerated the rate at which it occurs.



- Human population has increased due to increased birth rates and reduced mortality rates.

Current World Population

Human population growth

- Human population growth exacerbates every other environmental problem.
  - Use of resources inevitable

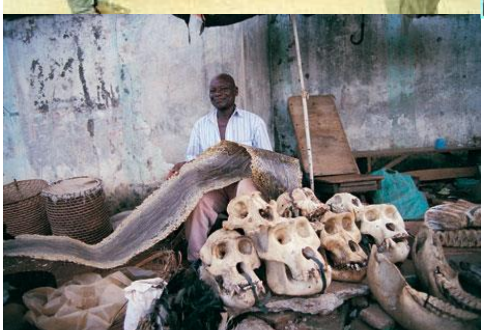
- The ***impact (I)*** of population growth is the result of ***population size (P),*** the level of ***affluence (A)*** measured as the *per capita consumption*, and the ***technologies*** *and socio-political-economic arrangements* ***(T)*** required to service the consumption.

I = PAT

- Human impacts may be felt at great distance
  - the concept of ***ecological footprint*** (the influence of a group of people on both the surrounding environment and locations across the globe, Rees 2001).
  - Citizens of developed countries have wider footprint than those of developing countries.

- The Way Forward: *"Live simply so that others may simply live"*

Overexploitation



- Increased demand for natural resources as standard of living improves.

- Inefficient and wasteful use of natural resources.

Natural Resource Consumption and Sustainable Development

BIOL 452 Biodiversity Conservation and Utilization Lecture

Natural Resources

Goods and services supplied by the environment.

Basis of life on earth; some satifying our wants.

Two types of natural resources

Renewable natural resources

– Replaced by natural processes faster than they are consumed.

– Replenish themselves in a relatively short time.

Two types of natural resources

Renewable natural resources

– Quantity not noticeably affected by human consumption.

– E.g., forests (plants and animals), soils, water, wind, solar, etc.

Two types of natural resources

Non-renewable natural resources

- Limited in quantity; finite.
- Used at a faster rate than nature can replenish them.
- May be replaced by natural processes *over extremely long periods of time* not useful to humans.

Two types of natural resources

Non-renewable natural resources

- May be *recyclable* but overall supply remains relatively constant.
- E.g.,fossil fuels, minerals, etc.

Consumption of Non-renewable Natural Resources

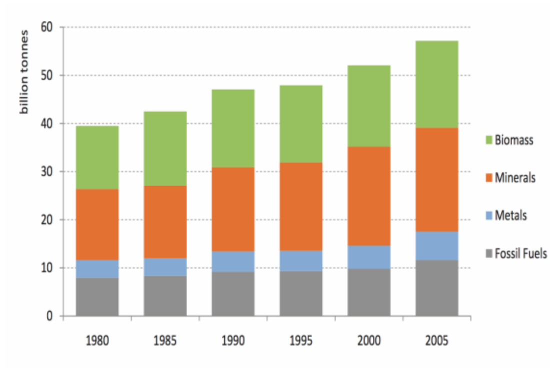
Humanity's consumption of non-renewable natural resources is increasing mainly due to:

- Increasing human populations
- *Per capita* demand rises.

Global extraction of natural resources, 1980 to 2005

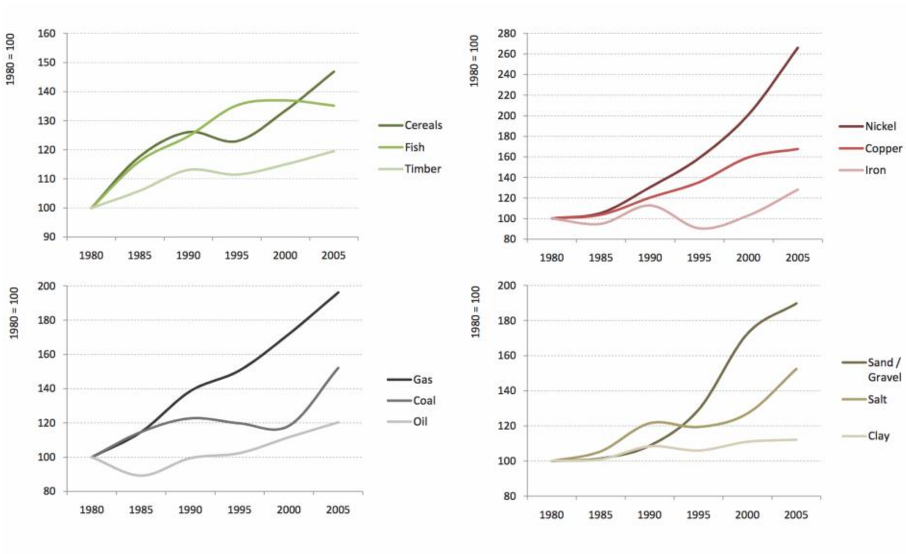
Humans extracted and used ~ 50% more natural resources between 1980 and 2005.

- About 60 billion tonnes a year.
- 100 billion tonnes by 2030.

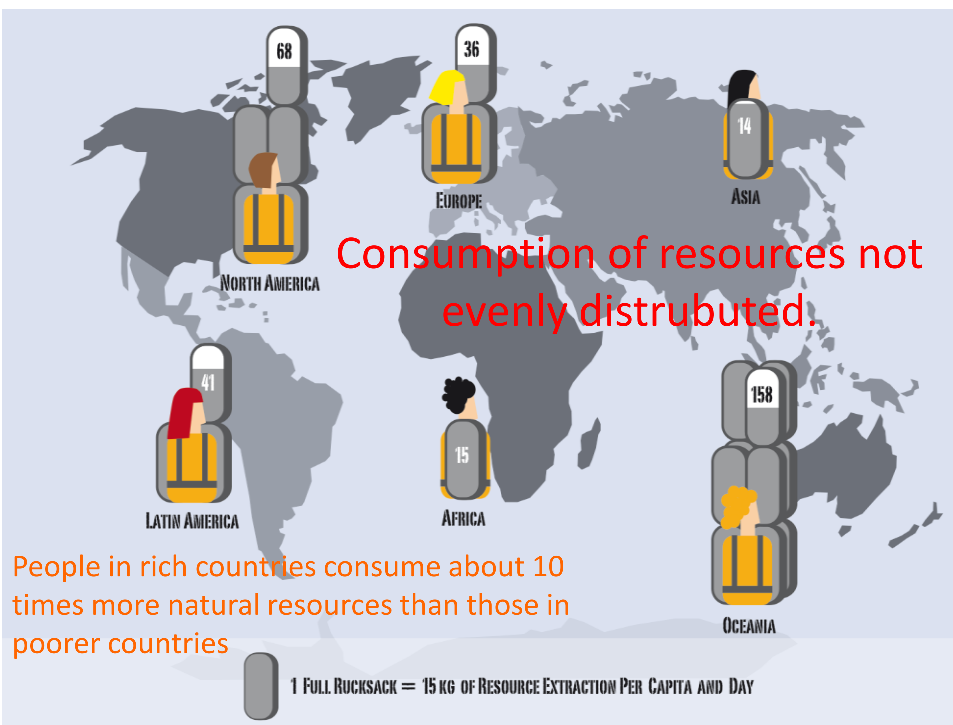


Credit: SERI

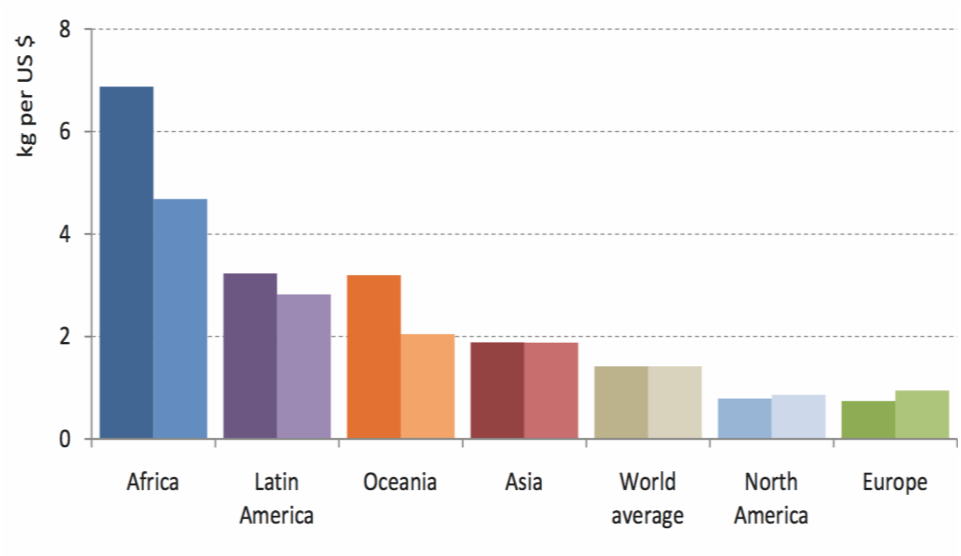
Trends in world-wide resource extraction of selected minerals, 1980 to 2005



Credit: SERI



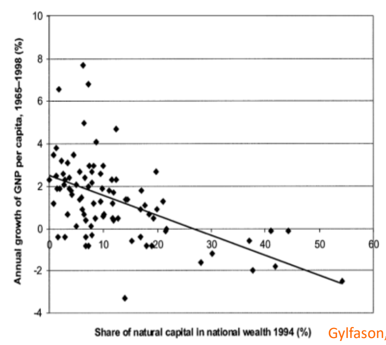
Resource extraction (darker column) and consumption (lighter column) in kg per US$ of GDP, 2000



Credit: SERI

What are the effects of increasing natural resource consumption?

- Slows down economic growth (the natural resource curse).
- Generates lots of waste.
- Damage to the environment.
- ***Increases threat*** to natural resources, raising the issue of ***sustainability***, and the need for ***conservation***.



Gylfason, 2001

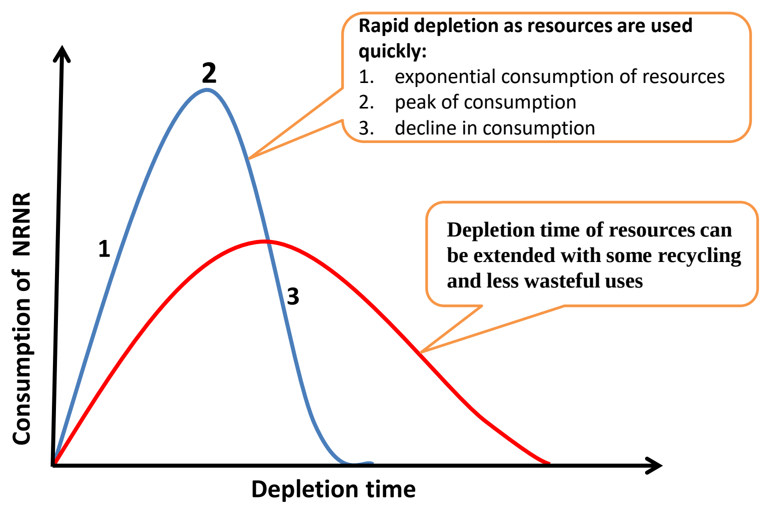
What is sustainable resource use?

- Using resources at a rate at which they can be replaced or recycled while preserving the long-term environmental health of the biosphere.

- Can be practiced through
  - Recycling
  - Conserving
  - Preserving ecosystems
  - Using the environment responsibly

Two schools of thought regarding sustainability of resource consumption and availability

1. Malthusian view



1. Malthusian view

- Most resources would become exhausted.
- Finding new resources cannot sufficiently extend the depletion curve.
- Peak of consumption always followed by a decline; resources become more difficult to find and process.
- Technology will not overcome inevitable shortages.

1. Malthusian view

- Energy requirement to exploit previously inaccessible or less concentrated resources may not be met.
- Malthusians advise us to
  - Cut back on growth
  - Conserve resources
  - Recycle resources when possible

2. Cornucopians view

- Technology will put off the day when no further exploitation is possible.
- Improved technology will make it possible to
  - Find new resources
  - Exploit new reserves
  - Substitute one mineral or energy source for another.

2. Cornucopians view

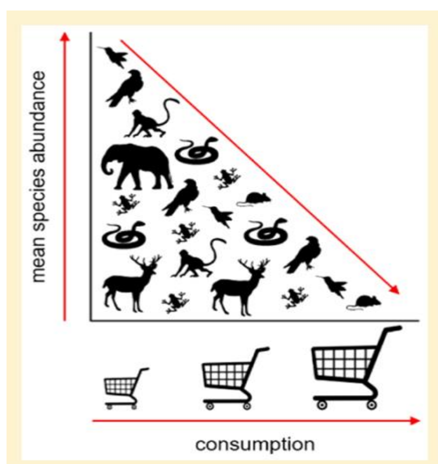
- Poorer grades of mineral ores may be utilized.
  - E.g., 0.3% copper ore can be used now as opposed to 3% in the past.
- Nuclear energy will help meet the energy requirement.
- Given time, a new plenty energy source would be found.

Nuclear energy plant

Human Consumption and Biodiversity Loss

Biodiversity Footprints of Rising Human Consumption

- Rising consumption of goods and services in modern industrialized societies adversely affects biodiversity and ecosystem services.
- That is **consumption-based biodiversity losses** or **biodiversity footprint**.



Wilting et al. (2017). Quantifying biodiversity loss due to human consumption: a global-scale footprint analysis. American Chemical Society Publications. 9pp.

Table 2. Total (Million MSA-loss·ha·yr) and Per-Capita Biodiversity Footprints (MSA-loss·ha·yr) of 10 Countries/Regions in 2007[a]

country	total footprint	footprint per capita	domestic share (%)	import share (%)	land use (%)	GHG (%)
Africa	668	0.7	94	6	90	10
China	539	0.4	89	11	48	52
Europe	811	1.4	70	30	55	45
India	281	0.2	91	9	65	35
Japan	138	1.1	46	54	48	52
North America	977	2.2	83	17	58	42
Oceania	162	4.6	89	11	78	22
Rest of Asia	783	0.6	82	18	66	34
Russia	348	2.4	92	8	77	23
South America	539	1.2	94	6	80	20
World	5246	0,8	100	0	66	34

[a]Contributions of domestic and foreign pressures, and GHG emissions and land-related pressures.

- Biodiversity footprint per citizen show large variations across countries, with higher values when *per-capita* income increases.
  - Higher in Australia, Canada, Finland and USA
  - Lower in China, India, and Indonesia
  - In Europe, 2-3 times higher than available areas on the continent.

Wilting et al. (2017).

Trade in Biodiversity Footprint

- Telecoupling of environmental and socioeconomic systems over large distances
  - Reliance on resources cultivated, extracted or processed in other parts of the world.
  - More than 50% of footprint occurring in faraway places. E.g., 30% of global species threat in Global South attributed to production of agricultural materials, textiles and other raw materials destined for consumption in the Global North

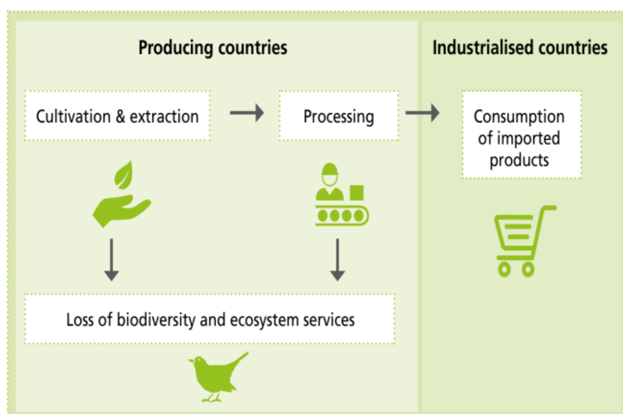


Figure 1: How consumption leads to loss of biodiversity and ecosystem services worldwide

Kliem et al. (2019). Sustainable consumption for biodiversity and ecosystem services: the cases of cotton, soy and lithium. Federal Agency for Nature Conservation, Germany. 84 pp.

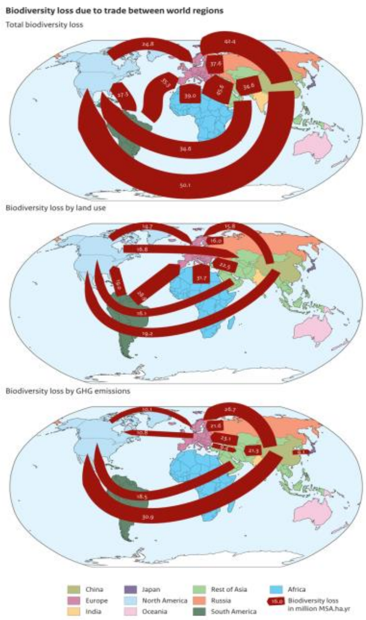


Figure 2. (a−c) Trade in biodiversity loss among 10 world regions and countries, and for the primary pressure categories (total, land use, and GHG emissions). Each part shows the ten trade flows causing the highest losses. The arrows start in the regions where the pressures take place and end in the consuming regions. Losses are measured in million MSA-loss·ha·yr.

- Europe, North America and Japan imported far more biodiversity losses than they exported.
- Large countries such as Brazil, Russia, India, Australia, China and Indonesia imported less (< 15%) because they are self-sufficient in producing food products.

Table 2. Total ... iodiversity Footprints (MSA-loss·ha·yr) of 10 Countries/Regions in 2007[a]

country	domestic share (%)	import share (%)	land use (%)	GHG (%)
Africa	94	6	90	10
China	89	11	48	52
Europe	70	30	55	45
India	91	9	65	35
Japan	46	54	48	52
North America	83	17	58	42
Oceania	89	11	78	22
Rest of Asia	82	18	66	34
Russia	92	8	77	23
South America	94	6	80	20
World	100	0	66	34

[a]Contributions o... ions and land-related pressures.

Most of the biodiversity losses were caused by land-use related pressures.

Wilting et al. (2017).

Environmental Pressures Underlying Biodiversity Footprint

Table 1. Attribution of Environmental Pressures and Biodiversity Impacts to Economic Sectors and Consumers[a]

environmental pressure	biodiversity impacts due to	biodiversity loss factors	attributed to
land use	habitat replacement by cropland (ha·yr)	MSA-loss per ha of cropland	crop sectors (1−8)
	habitat replacement by pasture (ha·yr)	MSA-loss per ha of pasture	livestock sectors (9−12)
	habitat replacement by forestry (ha·yr)	MSA-loss per ha of forestry	forestry (13)
	habitat replacement by urban area (ha·yr)	MSA-loss per ha of urban area	consumers
	fragmentation by cropland (ha·yr)	MSA-loss per ha of cropland	crop sectors (1−8)
	fragmentation by infrastructure (km·yr)	MSA-loss·ha per km road length	all sectors (except agriculture) and consumers
	disturbance by infrastructure (km·yr)	MSA-loss·ha per km road length	all sectors (except agriculture) and consumers
	encroachment (MSA-loss·ha·yr)		consumers
GHG emissions	climate change (kg CO_2-equivalents)	MSA-loss·ha·yr per kg CO_2-equivalents	all sectors and consumers

[a]For sector numbers, see Table S2.

Wilting et al. (2017). Quantifying biodiversity loss due to human consumption: a global-scale footprint analysis. American Chemical Society Publications. 9pp.

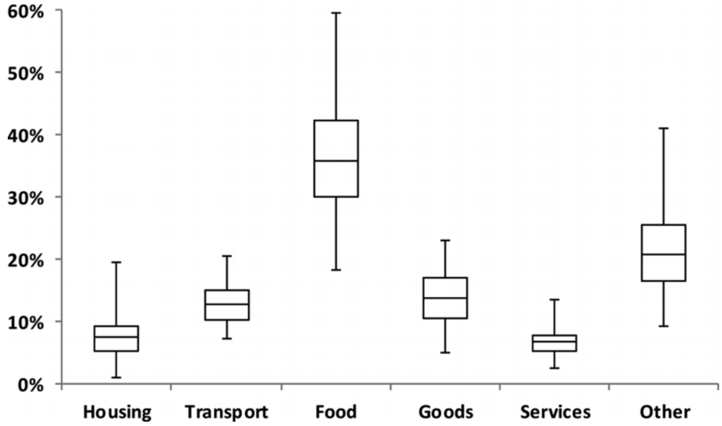


Figure 1. Contribution of different categories of consumption to total biodiversity loss due to GHG emissions and land use. Boxes show the first and third quartiles (25−75%), and whiskers show the ranges for 45 countries/regions. The consumer demand for each of the 48 industries was aggregated to six main consumption categories, i.e., housing, transport, food, goods, services and other consumption; "other" includes category "Not allocated" (see SI, Text Section S5 and Table S3).

Food consumption is the most important driver of biodiversity loss in many countries and regions.

Wilting et al. (2017).

Key Impacts of Human Consumption on Biodiversity

- **Loss of habitats**
  - Often the results of change in land use as production sites expand to meet increasing demand
  - Most important global driver of biodiversity loss
- **Pollution of water and soil**
  - Linked to industrial agricultural processes
  - Primarily caused by agrochemicals and chemical agents used in processing
- **Loss of freshwater resources**
  - Irrigation and resource extraction processes often required enormous amount of water.

Kliem et al. (2019)

Case Study: Cotton Consumption in Germany

- Cotton is one of the main resources of Germany's clothing industry
  - Cotton accounts for 30% of total textile fibre consumption worldwide.
  - Germany consumed approx. 4% (i.e., 760,000 tonnes of textiles, 218,000 tonnes of fibre, yarn and fabric) of the 25 m tonnes of cotton produced worldwide in 2016.
  - Imported 64% of its cotton from India, China, Pakistan and Turkey.

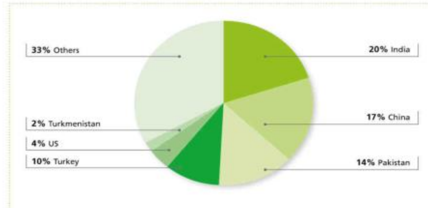


Figure 7: Origins of cotton imports to Germany in 2016; *Source: Eurostat Comext*

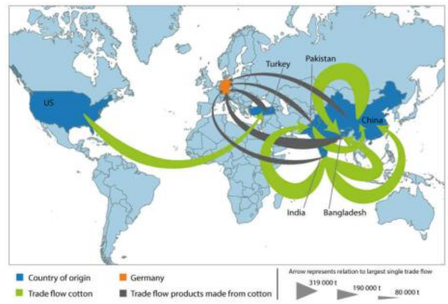
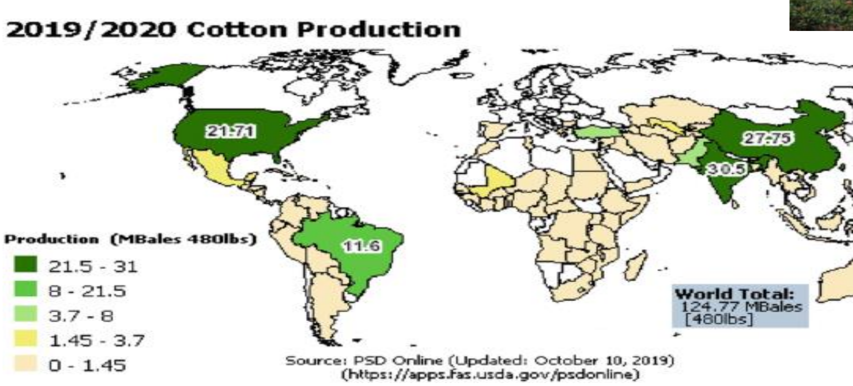


Figure 8: Trade flows of cotton and cotton products imported into Germany from outside the EU in 2016 (in tonnes); *Source: Eurostat Comext*

Case Study: Cotton Consumption in Germany

- Cotton is a water-intensive, pest-prone crop, grown primarily in semi-arid, water-scarce regions.



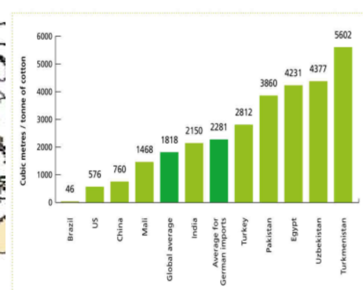


Figure 9: Average irrigation water usage per tonne of cotton production by country
Source: Chapagain et al. (2006), see endnote 44

Case Study: Cotton Consumption in Germany

- Impacts on biodiversity
  - Large-scale cotton irrigation can lead to changes of an entire aquatic ecosystems.
    - 2,300 million cubic metres of water required annually to satisfy the cotton deman of German consumers.
    - Enough water to fill 920,000 Olympic-size swimming pools
  - Cotton cultivation relies heavily on the use of pesticides and other agrochemicals.
  - Processing such as dyeing and textile finishing brings about additional environmental pressures in producer countries.

Main drivers	Impact on biodiversity	Impact on ecosystem services
Land conversion	→ Loss of highly biodiverse forests and grasslands → Destruction and changes in habitats threaten species	→ Depletion of permanent soil cover and associated functions → Depletion of carbon storage → Loss of buffering soil functions
Agricultural intensification	→ Reduced biodiversity due to intensive use of agrochemicals, especially pesticides → Decreased agrobiodiversity due to monoculture production → Loss of genetic diversity due to increasing use of genetically modified varieties	→ Contamination of river systems, groundwater and aquifers → Long-term persistence of pollutants in soils, reducing soil function → Reduction of pollinators and associated functions
Irrigation	→ Loss of aquatic habitats due to lake and river drainage	→ Severe changes in the hydrology of entire landscapes leading to water scarcity → Increased salinisation degrades soil fertility

Table 7: **Main impacts of cotton cultivation for biodiversity and ecosystem services**

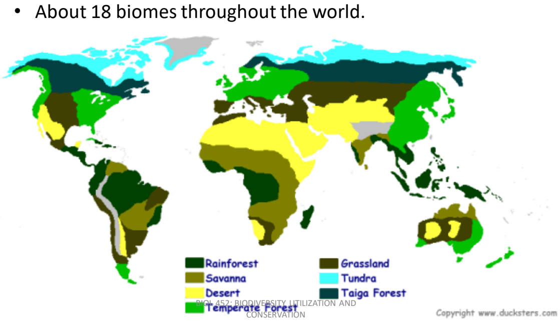
Kliem et al. (2019)

Biodiversity Loss in Tropical Ecosystems

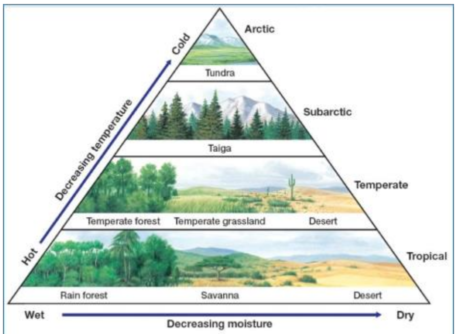
- In a statement by Tilman (2000), “the earth will retain its most striking feature, its biodiversity, only if humans have the prescience to do so.

Biomes of the World

- Large-scale patterns in vegetative structure and dominance.
- About 18 biomes throughout the world.



Biomes are a function of temperature and precipitation

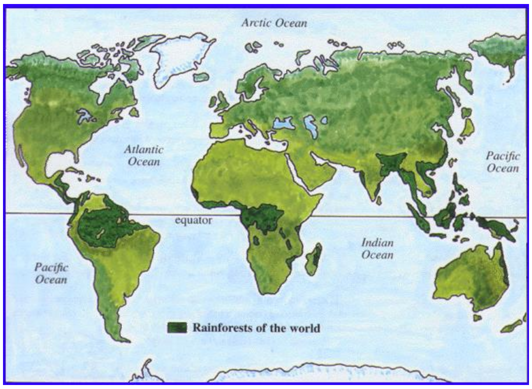


Tropical Rainforest

- The term 'tropical forest' was first coined by Schimper in 1897 in his book 'The Plant Geography.'
- Described by Humboldt as **evergreen land, hygrophilous in character, at least 30m high, but usually much taller, rich in thick-stem lianas and in woody as well as herbaceous epiphytes.**

Where are the tropical rainforest found?

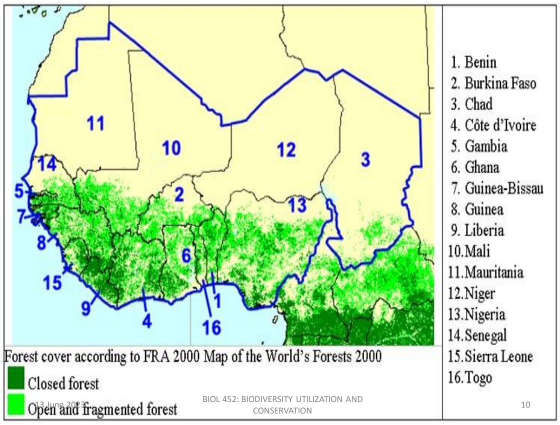
- Along the equator in Southern America, Asia, Africa and Australia.
  - $\pm$ 10º from the equator.



Distribution of TRFs

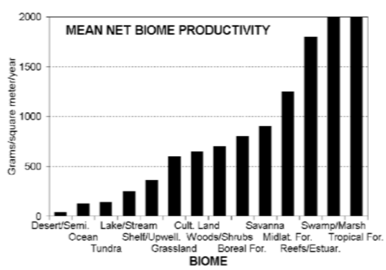
- Largest expanses in the Amazon Basin of South America, Indo-Malaysian region, Congo and West Africa.
- Africa has about 20% of the world's tropical forest
  - 10% of which is found in the south coast of West African (the Upper Guinean Forest).

The Upper Guinean Forest



Tropical Rainforest

- > 250 cm of rainfall each year.
- Most productive biome on earth
  - 10% of land, but 30% of **net primary productivity**

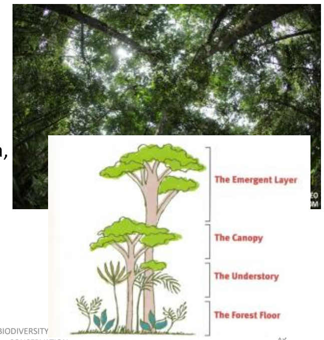


Tropical Rainforest

- Most biologically diverse terrestrial ecosystems.
  - Contains ca. 50 – 90% of all species in the world.
    - two-thirds of the estimated 250,000 plant species.
    - 90% of insects, etc.

Characteristics of the Tropical Rainforest

- Dominated by woody plants, which form a ***continuous layered canopy cover***.
- This continuity distinguishes forest vegetation from savanna, and its also the reason for the **paucity of grasses**.
- Many lianas (vines) and epiphytes.
  - Strategies of non-trees to reach light.



- Animal life equally abundant and diverse:
  - ✓ invertebrates and insect exceedingly numerous.
  - ✓ relatively small number of large and conspicuous mammals, but many more species of other vertebrates especially birds than in comparative areas of temperate zone.

- High diversity of life adapted to the prevailing conditions
  - high precipitation, humidity and year round warm temperatures, lots of solar energy.
- Biotic factors more commonly limit population growth than in other regions of the earth.
  - ✓ there is a high degree of interdependence or interaction among plants, animals, climate and soil.

Tropical Rainforest

- Most soils are infertile
  - Nutrients are in living biomass and litter layer.
  - Growth limited mostly by phosphorus.
- Decomposition drives nutrient availability.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 16

Status of Exploitation of the TRF

- Each year, an estimated 13 million hectares of TRF is cleared, representing 1% of the remaining 40% of original forest areas in the world (FAO, 2005).
- In Ghana, for instance, almost 90% of the original forest cover has been lost since 1940:
  - 22,000 hectares deforested each year.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 17

- Forest decline is the result of action of a number of ***agents*** who exploit the forest in unsustainable ways in search of profit and means of subsistence:
  - ✓ slash-and-burn farmers
  - ✓ commercial farmers
  - ✓ cattle ranchers,
  - ✓ loggers
  - ✓ mining and petroleum industrialist
  - ✓ land settlement planners,
  - ✓ infrastructural developers, etc.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 18

Forest Exploitation in Ghana

- Slash-and-burn agriculture
  - Taungya farming, for example
  - Used to be sustainable but no longer considered as such due to increasing population

Forest Exploitation in Ghana

- Logging

Forest Exploitation in Ghana

- Mining

To Exploit or Not to Exploit

The dilemma of African countries

- Exploitation of forest resources exerts many devastating impacts on the forest ecosystem, despite emphasis on sustainable harvesting and regenerative capacity.

Negative impacts of logging

- Forest road network destroys 5-6% of tree cover.
- Felling destroys about 5% of surrounding trees.
- Living and processing areas can destroy 0.5-0.6% of forest area.
- Generally, logging destroys more than 6-9% of the forest canopy if extraction is restricted to 10-15 m/ha.
- Ecologists tend to blame only timber exporters for these impacts.

Benefits of forest exploitation

- Forest exploitation is often one of the principal means of earning convertible currency.
- It may be the one and only silvicultural activity carried out on matured forest (Anning's paper).
- Forest utilized in this way will be better protected from agriculture than unmanaged forests, because it generates income.

What is the Way forward?

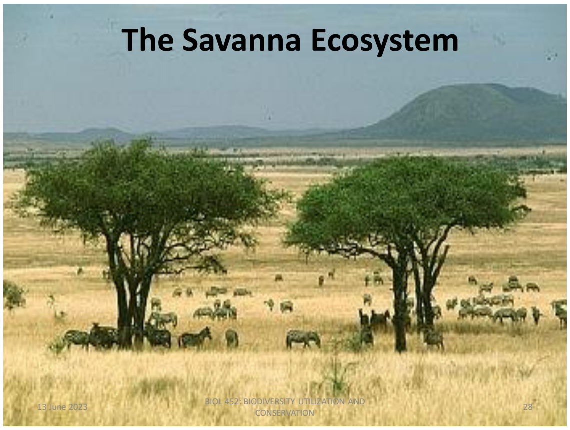
- Development must be rationalised to protect the future of the forest and to conserve its biodiversity.
- Exploitation must be ***progressive and selective***.
  - ✓ there are 300-600 tree species but only about 100 have any recognised technical value, and 30-50 are habitually exploited for profit.
  - ✓ usually an average of 0.5-3 plants is cut per ha, thus exploiting only 4-25 m^3 when trees of more than 10 cm dbh are considered.

The Way forward

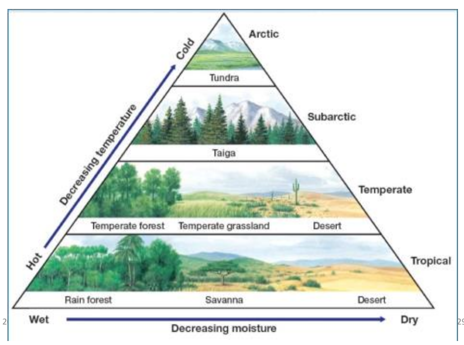
- Felling should be based on carefully compiled and up-to-date forest inventories and should remain moderate.
  - annual quota fell per hectare should not exceed annual growth rate.
- Extraction methods must be improved.
  - fellers and loaders must be trained
  - road network must be developed to take into account potential rich forest areas.

Conclusion

Conservation of the TRF, irrespective of the approach or where it is carried out must be geared toward the same result – marrying the requirements of production to those of conservation.



Biomes are a function of temperature and precipitation

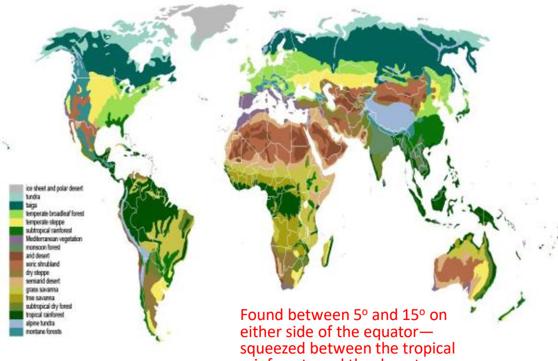


13 June 2 … 29

The Savanna Ecosystem

- A range of vegetation types consisting **predominantly of grasses** but also varying in the amount of forbs, shrubs and trees.
- Commonly referred to as tropical grasslands
  - found in areas where it is warm year round
  - Reduced rainfall with prolonged dry season
- Maintained by periodic fires—fire adapted.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 30



Found between 5º and 15º on either side of the equator—squeezed between the tropical rainforests and the desert.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 31

The Savanna Ecosystem

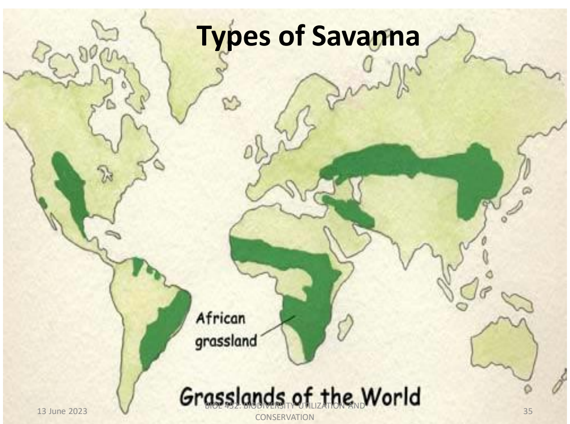
- Has large range of highly specialized plants and animals, which depend on each other to keep the environment in balance.

13 June 2023 BIOL 452: BIODIVERSITY UTILIZATION AND CONSERVATION 33

The Savanna Ecosystem

- Most of the plants shrivel up and die during the distinct dry season. Some rivers and streams dry up. Most of the animals migrate to find food.
- In the wet season, all of the plants are lush and the rivers flow freely. The animals migrate back to graze.

Types of Savanna



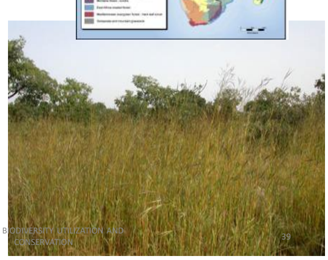
Types of Savanna

- Different types of Savanna can be found around the world; in Africa, South America, Australia, etc.
- The largest and most familiar is the African Savanna, of which the Serengeti Plains of Tanzania are the most well known.
- The African savanna covers almost half of the land area of the continent (ca. 5 million square miles).

Types of Savanna

- In broad terms, three main types of savanna can be recognised in West Africa:
  - ✓ Guinea Savanna
  - ✓ Sudan Savanna
  - ✓ Sahel Savanna
- **Derived savanna**
  - a region that was formerly high forest but in which the original large trees have now been destroyed and replaced by Guinea Savanna species.

- **Guinea Savanna**
  - relatively moist with rainfall between 900 and 1500 mm per year, nearly all of which falls in 7-8 months of the year.
  - Trees are mostly broad-leaved species up to 12-15 m high, and forming in some places an almost closed canopy of branches.



- **Sudan Savanna**
  - Lies to the north of the Guinea savanna, and covering a greater part of Burkina Faso and Mali.
  - Annual rainfall between 600-900 mm per year
  - Drought is severe and lasts for approximately 7 months from October to April.

- **Sahel Savanna**
  - Lies further north of the Guinea, with an annual rainfall of roughly 250 – 600 mm.
  - Dry season is more intense than that found in the Sudan zone.
  - Grasses are sparse and less than 1 m tall.

Status of Exploitation of the Savanna

- The savannas contribute immensely to world food supply by representing productivity within reach of heavy grazing animals.
- However, there are only few ecosystems that have been more badly damaged by man's activities than the savannas used as grazing lands.
- Although education, social and political factors are often implicated, an underlying cause has been the ***lack of understanding of the principle of rangeland ecology***.

- Among the ecological characteristics of rangelands, **climate variability and its effect on soil and vegetation** are of prime importance.
  - Management must be based on expectation of drought.
- Special attentions should also be given to **conservation of soil and grass cover.**
- Control of **the numbers and distribution of grazing animals** particularly important.

Influence of Grazing on Savanna Vegetation

- Most grasslands have evolved under the influence of grazing animals.
  - In the absence of grazing, different vegetation would prevail.
  - In the presence of excessive grazing the vegetation alters in its general state and composition in a less desirable direction.
- Most, if not all plants, can tolerate some degree of use.
  - However, their response vary with the intensity and timing of that use.

Influence of Grazing on Savanna Vegetation

- Range grasses usually have three periods in each year when they are most vulnerable to grazing pressures.

Influence of Grazing on Savanna Vegetation

1 

2 

3 

1. **the start of the growing season**
   - Plant dependent upon reserves of nutrients stored in the seed or nutrients from the previous year's growth.
2. **after the main growth of the season is completed**
   - Plants are maturing and developing into seed crops.
   - use at this time can prevent seeds from being set and thus, endanger reproduction.
3. **at the end of the growing season**
   - plants are storing up nutrients for the following year's growth or regeneration.

Reading assignment

Read on the effect of nomadism on rangeland biodiversity.

Vegetation Types in Ghana

- Two major biomes are represented in Ghana.
  - ✓ **Tropical High Forests** supported by the southern half of the country.
  - ✓ **Savannas or woodland** mainly supported by the northern half of the country.

Vegetation Types in Ghana

- The savanna is mainly of the Guinea type, but an area of Sudan savanna occupies the north-easternmost conner of the country – known as the Navrongo-Bolgatanga-Bawku corridor.
- These vegetation types are not uniform or homogenous; many variants occur in each type.
- The closed or high forest zone is made up of different types, ranging from wet evergreen (WE) rainforest to dry semi-deciduous (DSD) forest.

Forest types in Ghana

Decreasing amounts of rainfall

- **Wet Evergreen** → Looks green and luxuriant all year round. Found in Axim area.
  - Upland evergreen
- **Moist Evergreen** → Differs from the WE in terms of floristic composition. Located around Tarkwa, Dunkwa, Enchi
- **Moist Semi-Deciduous** → Have a more clearly-defined dry season. Located around Goaso, Dormaa Ahenkro, Obuasi, Kumasi, Oda. Many of the species exhibit the deciduous habit.
  - Northwestern type
  - Southeastern type
- **Dry Semi-Deciduous** → Also known as the Transitional zone. X'terised by low amount of rainfall and pronounced dry season. Found around Ejura, Techiman and Wenchi.
  - Inner zone subtype
  - Fire zone subtype
- **South East Outliers** → The driest and least extensive of all forest types in Ghana. Accra plains, eg. Shai Games Prod. Res.

Wetlands

Wetlands

- Low-land ecosystems where the water table is at or above the level of the ground most of the year.
- Described by the **Ramsar Convention** as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, including areas of marine water, the depth of which at low tide does not exceed six metres".
- Transition zones between dry upland ecosystems and deep aquatic habitats.

There are two broad types of wetlands: Estuarine and Freshwater

- Estuarine
- An estuarine is a semi-closed body of water with variable salinity intermediate between salt and freshwater.
- Examples: lagoons, tidal creeks, river mouth.
- Roles:
  - habitat for marine organisms
  - Source of food
  - Traps useful nutrients
  - Flood prevention
  - Provides irrigation water

Freshwater

- Freshwater ecosystems may be subdivided into swamps, marshes, bogs, etc. based on soil types and plant life.
- Swamps are generally found in sheltered arms of lakes or gentle rivers, at the edges of standing waters.

A regularly flooded swamp

- Mangrove swamp forests -- found in sheltered muddy shores where the land is rapidly encroaching on the sea in a estuarine situations (i.e., a distinct saline woodland).
- The mangroves consist of a group of plants inhabiting tidal lands in the tropics or subtropics.
- Vegetation consists of trees and shrubs with palms, like Raphia, being characteristically present. Larges trees less common; but show the layering characteristic of tropical forests. Lianas and epiphytes present. Ground flora dominated by the Cyperaceae.
- Mangroves dominate three-quarters of tropical coastlines.

Mangrove forests

- A good example of convergent evolution, because they have a number of marked structural characteristics in common, although the plants are derived from many different families.

Mangrove forest

Mangrove forests

- The intertidal existence represents the major limitation to the number of species that are able to thrive in this habitat
  - plants must be able to tolerate broad ranges of salinity, temperature and moisture.
  - plants require a number of physiological adaptations to overcome the problems of anoxia, high salinity and frequent tidal inundation.

Economic importance of mangrove forest

- Mangrove forests are of special scientific interest by virtue of their structure and physiological adaptation.
  - use for reclamation of land from the sea
  - use as fuelwood and timber
  - constitute a source of chemical called tan bark which is used as dye
  - they support a rich and varied animal life of which many of the species are adapted to amphibious and saline habitats.
  - they are also used as excellent areas for rice cultivation.

CASE STUDIES OF ENVIRONMENTAL AND SOCIAL CONSEQUENCES OF ECONOMIC DEVELOPMENT AND CONSERVATION IN TROPICAL CLIMATE

The Nakdong River Basin in South Korea

RIVER BASIN DEVELOPMENT

- One of the most common types of river basin development is the **construction of man-made lakes or reservoirs.**

Bui dam project

RIVER BASIN DEVELOPMENT

- The reservoirs are usually built for some primary purposes:
  - ✓ hydropower generation
  - ✓ Irrigation
  - ✓ flood control

- An integrated series of benefits may often be projected that include other benefits:
  - ✓ fisheries
  - ✓ transportation
  - ✓ provision of domestic and industrial water supplies
  - ✓ recreation

Limitation by Ecological Factors

- These development activities, like all others that take place within a natural ecosystem, are subject to the limitations of ecological factors which operate within the ecosystem.

Problems of River Basin Development

Impacts on fishes

- The creation of man-made lakes usually results in a **shift from riverine conditions and fish communities to lacustrine ones**.

- The lake waters will be colonised by riverine fishes
  - ✓ some of which will be able to exploit the changed conditions and flourish
  - ✓ others will vanish from the fauna as they cannot cope with the changed feeding or breeding conditions.

The Volta Experience

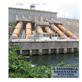
The Volta Experience

- Constructed in 1961
- To supply hydroelectric power for Ghana

The Volta Experience

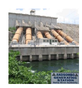
- After the construction of the Volta Lake
  - the mormyroid fishes were the first to disappear from the fauna as the lake filled, perhaps due to their benthic feeding habit and the fact that the bottom of the new lake was de-oxygenated.

The Volta Experience



- After the construction of the Volta Lake
  - Some characid fishes which had to move upstream to spawn vanished after some months.

The Volta Experience



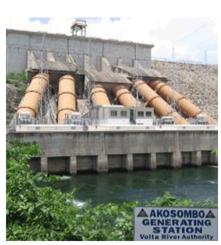
- After the construction of the Volta Lake .
  - **Cichlids** throve, as did **Schilbeid cat fishes** which changed from bottom-feeding to crop the burrowing *Ephemeroptera* nymphs which became abundant in the deadwood of tree downed by the rising river.

Cichlid fishes

Schilbeid cat fishes

The Volta Experience

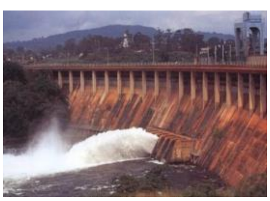
- After the construction of the Volta Lake .
  - Another problem is the **shifts in salinity and turbidity or chemical changes in estuarine and adjacent marine areas** which have significant impacts on marine fish and shell fish.



The High Aswan Dam (HAD)

The High Aswan Dam

The construction of this dam in 1964 brought about the collapse of a major sardine fishery which accounted for upwards of half of Egypt's total marine catch.




The High Aswan Dam

- Before the HAD was constructed, the annual flow of water from the River Nile (**Nile Stream**) stabilized the mediterranean ecosystem by continually supplying nutrient-rich sediments to these systems or water.


Nutrient-rich sediment from the Nile Stream was useful for agriculture

The High Aswan Dam

- However, this flow was cut after the construction of the dam, resulting in severe erosion along the Egyptian coast and decrease in fertility of the waters.

The High Aswan Dam

- The decrease in fertility in turn led to reduced primary productivity by the phytoplankton which provided sustenance to the sardines and other pelagic fishes.
- It also constituted a large source of detrital material, the products of organic decay, which forms a vital source of food for commerically valuable organisms such as shrimps.
- The fish industry in Egypt finally collapsed.

Spread of Aquatic Weeds

- Irrigation and hydropower projects may increase evapotranspiration loss due to invasion by water hyacinth (*Eichhornia crassipes*) and other weeds such as water lettuce (*Pistia stratiotes*).
- Besides the increase in evapotranspiration, blockage of navigation and damage to fisheries, *P. stratiotes* also poses a significant health threat.
  - the plant is a favourate habitat for the larvae of several mosquito species, which obtain oxygen from the water lettuce root and never have to surface.
  - control of the water weed is the only effective means of disease control.

Aquatic invasion of the Barekese dam

Lake Brokopondo Experience

Lake Brokopondo Experience

- A comprehensive study of the ecological impacts of water hyacinth on Surinam's Lake Brokopondo have been undertaken since its establishment in 1964.
- According to this study, water hyacinth was scarce in the river prior to inundation.
- By December, 1964, it covered 5000ha, 17900ha by June, 1965 and 41200ha by April 1966 (53% of the total lake area).

Lake Brokopondo Experience

- A control programme utilizing 2, 4 – D was initiated at an annual cost of $250, 000.
- In addition, there has been the cost of losses to water storage from evapo-transpiration and fishery having given a poor return in comparison with the previous riverine fishery.

Lake Brokopondo Experience

Table 2. Fish community parameters for Suriname River (pre-impoundment 1963-1964) and four different habitats in Brokopondo Reservoir in 1966-1967, 1978 and 2002-2005. Biomass of shore fish community in 1978 is given in kg per ha[1].

		Number of specimens	Biomass (kg)	Number of species	Species diversity *H* (numbers / biomass)	Evenness *J* (numbers / biomass)
Suriname River 1963-1964		12842	176.4	172	4.11 / 3.76	0.80 / 0.74
Brokopondo Reservoir 1966-1967		-	-	62	-	-
Brokopondo Reservoir 1978	Open water	301	67.9	11	1.49 / 0.46	0.62 / 0.19
	Shore	2540	26.0[1]	31	1.48 / 2.26	0.60 / 0.65
	Total	2841	-	35	1.82 / 2.04	0.75 / 0.61
Brokopondo Reservoir 2002-2005	Open water	1511	110.9	10	0.88 / 0.62	0.38 / 0. 27
	Shore	2308	20.5	27	2.29 / 2.43	0.70 / 0.74
	Bay	2020	110.5	23	1.58 / 1.51	0.51 / 0.48
	Beach	636	5.2	11	1.31 / 1.81	0.54 / 0.75
	Total	6475	247.1	41	2.17 / 1.53	0.60 / 0.42

Schistosomiasis

- Perhaps the greatest current problem of man-made lake and irrigation projects in the tropics stems from snail-borne infections.
- The WHO considers this disease as one of the largest public health threats in developing countries.
- Under earlier conditions, the ecological relationship between parasite, the primary host (snail) and the secondary host (man) was in relative balance, and relatively low levels of the disease prevailed.

Schistosomiasis

- More recently however, excellent conditions have been created for the fast spread of the snail host, through
  - ✓ rapid human population growth with poor sanitary facilities,
  - ✓ increased mobility of infected people
  - ✓ the ever more frequent construction of reservoirs and perennial irrigation projects

Case history of a schistosomiasis control in Egypt

- An excellent study of the relationship between schistosomiasis and the transmission from seasonal to perennial irrigation has been made by Henry *et al.* (1972).
- The report concluded:
  - ✓ *Egypt, over hundreds of years, has become unbelievably infested with bilharzias.*
  - ✓ *Life expectancy of women in Sindbis, near the Qalyub region, was 27 years and of men 25.*
  - ✓ *The countryside of the Delta is virtually rotten with the disease.*

Case history of a schistosomiasis control in Egypt

✓ *The overpopulation in horribly crowded villages, the lack of sanitation and the near impossibility of building proper facilities for potable water and waste disposal, the many unfortunate daily practices that allow for an amazing exposure to infection – all contributed to make conditions in the areas where perennial irrigation exists almost impossible to control.*

Cichlids: Parrot fish

Conservation Principles and Strategies

Protecting Biodiversity

What is Conservation?

- Management of human use of natural resources to provide maximum benefit to the present generation while maintaining its potential to meet the needs of future generations – *IUCN*
- Conservation embraces *preservation*, *maintenance*, *sustainable utilization*, *restoration*, and *enhancement of the natural environment*.

Conservation Principles

- Current usage recognizes the complex relationships among humans, animals, plants and the physical environment.
- Conservation is a process, applied cross-sectorally; not an activity sector in its own right.

Principles of Conservation

- Conservation is planned management to
  - Prevent overexploitation, pollution, destruction or neglect
  - Ensure future usability of natural resources.
- Recognizes limited knowledge and understanding of ecosystems
  - Allows natural processes to predominate wherever possible.
- It promotes
  - Less wasteful use of resources
  - More efficient extraction methods and recycling
  - Search for alternative natural resources

Objectives of Conservation?

- Three main objectives:
  1. ***Maintain essential ecological processes and life-supporting systems.*** E.g., soil regeneration and protection, cleansing of water, nutrient recycling.
  2. ***Preserve genetic diversity***
     - Matter of both insurance and investment.
     - Basis of ecological processes and life-support systems
     - Basis of breeding programmes, scientific, technological and medicinal advances
     - Security of industries that use living resources
  3. Ensure ***sustainable utilization of species, ecosystems or natural resources***.

Types of Conservation

Soil conservation: soil is an important life-supporting system but threatened by human cultivation and climate change.

Water conservation: water is needed for food and industry.

Atmosphere conservation: we need clean air.

Wildlife conservation: preventing extinctions, maintaining biodiversity.

Energy conservation: energy is the driving force behind industry and civilization.

Urban conservation: deals with overcrowding, pollution, etc.

Marine conservation: different systems, rich in diversity.

Forest conservation: forests serve as home for many plants and animals.

Importance of Conservation

- Conservation is a response to a global environmental crisis that requires an immediate action.
  - Rapid human population expansion has led to unprecedented and unsustainable rates of natural resource consumption.
  - Humans activities continue to directly and indirectly deplete natural resource and threaten biodiversity, fast driving a number of them into extinction.
  - Human wellbeing and survival are directly linked to sustenance of biodiversity.
  - It is our responsibility to safeguard natural resources (biodiversity) for future generations.

Conservation and Development Aims

Development involves the use of natural resources.

Potential conflict between conservationists and developers.

Bui dam project

People whose primary concern is economic development	People whose primary concern is conservation
Place strong emphasis on quantitative production. E.g., Number of new acres brought under irrigation, increased yield of rice per acre.	Less emphasis on quantitative production. Inclined to ask: What desirable natural processes may be disrupted? What resources and values are sacrificed?
Interested in direct and readily measurable gains.	Look at direct and indirect socio-economic costs in the short-term, long-term, and the immediate benefits.

What are the Goals of Conservation?

- FAO and UNESCO defines conservation as the *rational use of the earth's resources to achieve the highest quality of living for mankind.*

- By this definition, such a conflict ought not emerge because both groups seek a common goal.

Kakum national park

Sources of the Conflicts between Conservation and Development Aims

- However, such conflicts may arise because:
  - the term **quality of living** is subjective and varies with cultur and economic status.
  - **Rational use** varies in interpretation.

Is it rational to mine a forested area?

Resolving the potential conflicts between conservation and development Aims

- Development provides the necessities of life and the material luxuries of civilizaton.
- Conservation assures that the environment is:
  - Satisfactory to the people involved.
  - Self-sustaining or capable of being sustained.
  - Heathful.
  - Challenging and offers opportunity for future change.

Role of ecological information in conservation and development

- Ecological knowledge essential to conservation as it is to development.
- Ignoring ecological facts may lead to failure of conservation efforts and waste of money.
- Range of conservation values to be considered in development planning ought to be related to ecological information. E.g., as obtained from EIA.

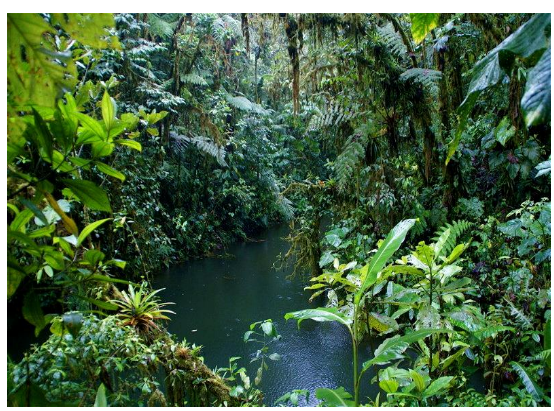
Role of ecological information in conservation and development

- Equally, the range of economic values must take into account the ecological information.
- Without these, sentiments and subjective evaluation or error of judgement will prevail.

Given a particular tract of land not yet opened to human use what options exist for its use?

Options for sustainable development of undisturbed lands

1. **Leave in completely natural state** to
   - maintain its biodiversity
   - reserve it for scientific study, educational use, watershed protection and for its contribution to landscape stability

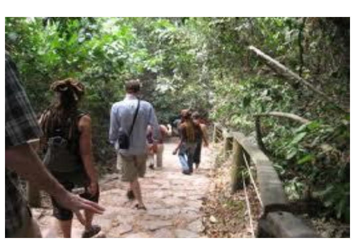


Options for sustainable development of undisturbed lands

2. **Developed as a National Park or equivalent reserve** with the natural scene remaining largely undisturbed to serve as
   - a setting for outdoor recreation
   - an attraction for tourism


Options for sustainable development of undisturbed lands

3. **Limited harvest of its wild vegetation or animal life but maintained largely in the wild state**, serving to
   - Maintain landscape stability
   - Support certain kinds of scientific or educational uses
   - Provide for some recreation and tourism
   - Yield some commodities from its wild populations.




Options for sustainable development of undisturbed lands

4. **Intensive harvest of its wild products as forest production, pasture production or intensive wildlife production**.
   - value as a wild area for scientific studies and tourism diminishes but not necessarily lost.
   - Its role in landscape stability and watershed stability is changed but may be maintained at a high level.

Options for sustainable development of undisturbed lands

5. The wild vegetation and animal life having been almost completely removed, it can be **used for intensive urban, industrial and transportation purposes**.

Options for sustainable development of undisturbed lands

- So long as the first three choices are taken, the option remains open to change from one of these uses to any other, as well as any of the last two.

- If the fourth choice is picked, the option for restoring the land into any of the first three categories are reduced but not eliminated.

Options for sustainable development of undisturbed lands

- Selection of the last option largely prohibits any shifts to the other alternatives within a reasonable period of time.

- A rational and sensible choice from the options available must be based on ecological and economic considerations, etc.

How can we conserve biodiversity?

- Two broad strategies are used
  - ***In-situ*** methods
  - ***Ex-situ*** methods

Ex-Situ Conservation

- Conservation and maintenance of components of biodiversity **outside their natural habitats**.

- Involves conservation of genetic resources as well as wild and cultivated species, and draws on a diverse body of techniques and facilities.

Examples of *Ex-Situ* Conservation

1. Gene banks, e.g., seed banks, sperm and ova banks, field banks.

2. In vitro plant tissues and microbial culture collections.

3. Captive breeding of animals and artificial propagation of plants, with possible reintroduction into the wild.

4. Collecting living organisms for zoos, aquaria, and botanic gardens for research and public awareness.

Ex-Situ Conservation

- Ex-situ conservation measures can be complementary to *in-situ* methods as they provide an "insurance policy" against extinction.

- They can be conveniently classified according to the part of the plant conserved:
  - ✓ whole plant or living collection
  - ✓ seeds banks
  - ✓ tissue or genetic materials in culture

Whole Plant Conservation

- This is also called living collection. E.g., botanic gardens, plantations, etc.

Advantages:
- Useful for display and education or research.
- Species take time to reach reproductive maturity.

Whole Plant Conservation

Disadvantages:

- High maintenance cost and large spatial requirement in the case of trees.
- Frequent controlled pollination and re-establishment required for annuals, unless vegetative propagation methods are available.
- There is a possibility of taxa hybridizing, controlled pollination is obligatory among out breeders.
- Suceptibility to communicable diseases within monocultures.

Whole Plant Conservation

Challenges:

- Plants will, as a rule, prosper outside their natural range in the absence of co-evolved pathogens, eg. *Hevea brasiliensis* flourishes in plantations outside their region of origin.
- However, this confronts political problem; should governments allow plantation forestry? If so, how much of land should be converted into plantations?

Seed Banking

- This refers to conservation of species through the storage of seeds.
- It is the most preferred method of *ex-situ* conservation.

Seed Banking

Advantages:

- The principal advantage is the economy of space
- Its demand for labour is low

Seed Banking

Disadvantages:

- Relies on dependable power supply
- Requires meticulous monitoring of germinability over time
- Periodic regeneration under conditions which minimize selection among residual seed stock.
- Difficulty in application to tropical tree species most of which lack dormancy and are also recalcitrant to induction of dormancy using current methods.

Tissue Culture

Advantages:

- Tissue culture expecially meristems can maintain genotypes unaltered for long period of time.
- Thus, it provides an economic means of suspending at least temporarily changes in gene frequency.
- Provides an invaluable alternative for conservation of multiple lines of taxa not easily conserved *ex-situ* on this scale by other measures, e.g., rainforest trees with recalcitrant seeds.

Tissue Culture

Disadvantages:

- Requires a great deal of expertise; each taxon has its own requirements for successful establishment in tissue culture and regeneration.
- At present, basic mechanisms are poorly understood so that successful techniques must be arrived at through tedious trials and errors.

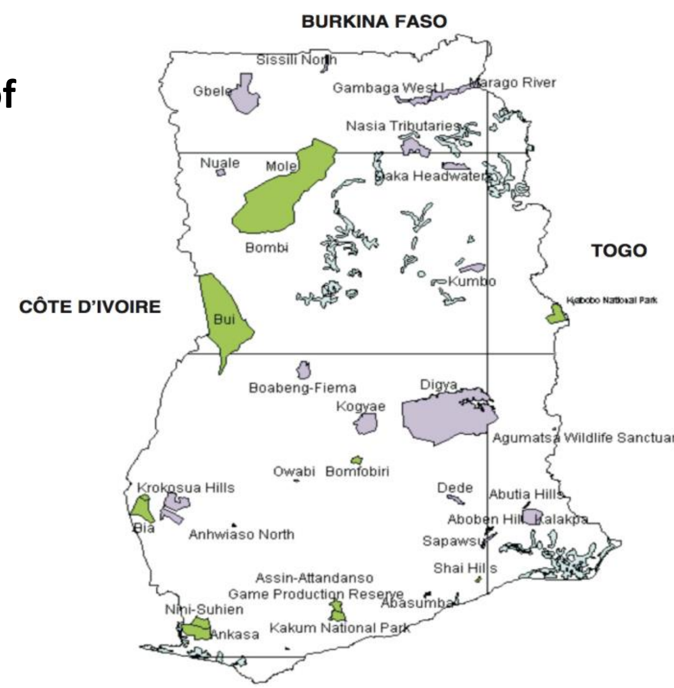
In-Situ Conservation

- Conservation of species in their natural habitats. i.e., protected areas including national parks, reserves, sanctuaries, sacred groves.
- These natural areas are used as "warehouses" of biological information.

In-Situ Conservation

- Considered the most appropriate way of conserving biodiversity.
  - As of 1993 nearly 7, 000 parks and protected areas covering over 650 million acres had been established worldwide.
  - Ghana has 21 protected areas including 7 NPs, 6 resource reserves, 2 wildlife santuaries, 1 Strict Nature Reserve and 5 Coastal Wetlands (IUCN, 2010)

Location of Protected areas in Ghana



Advantages of *In-Situ* Conservation

- Allows a population to maintain itself within the community of which if forms part and in the environment to which it is adapted.
- Allows indigenous species and systems to be protected, thus taking care of the unknowns until such time as methods are found for their investigation and utilization.
- Natural selection and community evolution continue and new communities, systems, and genetic material are produced.

Challenges of *In-Situ* Conservation

- Rigid preservation is virtually impossible to implement and even less likely to be maintained over time.
- There is a need to ensure that the genetic base of the population concerned is wide enough.
  - Demographic, environmental and natural uncertainties may cause significant reductions in the population of species.

Challenges of *In-Situ* Conservation

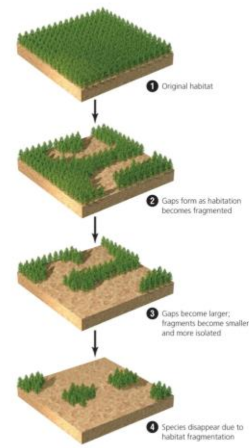
- Requires a greater knowledge of population structure, reproductive biology and gene flow than is normally available for most species.
- Needs international co-operation as in some cases a network of reserves within countries and sometimes spanning national boundaries becomes critical.
- *In-situ* conservation involves a series of planning and implementation requirement.

Practical Considerations

- Refuges, parks, preserves
  - How big should refuges be?
  - Where should they be?
  - McArthur & Wilson "Theory of Island Biogeography"
    - colonization rate
    - extinction rate (local)
    - predicts number of species

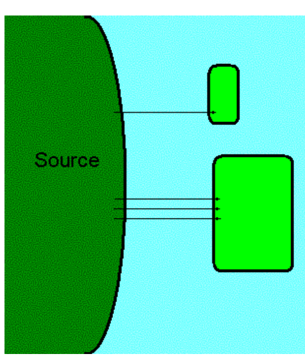
Practical Considerations

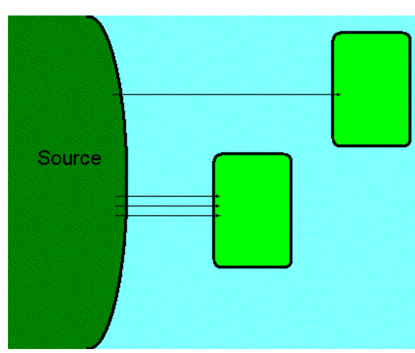
- Island Biogeography
  - Everyplace is an island
  - Habitat fragmentation
    - Smaller fragments hold fewer species



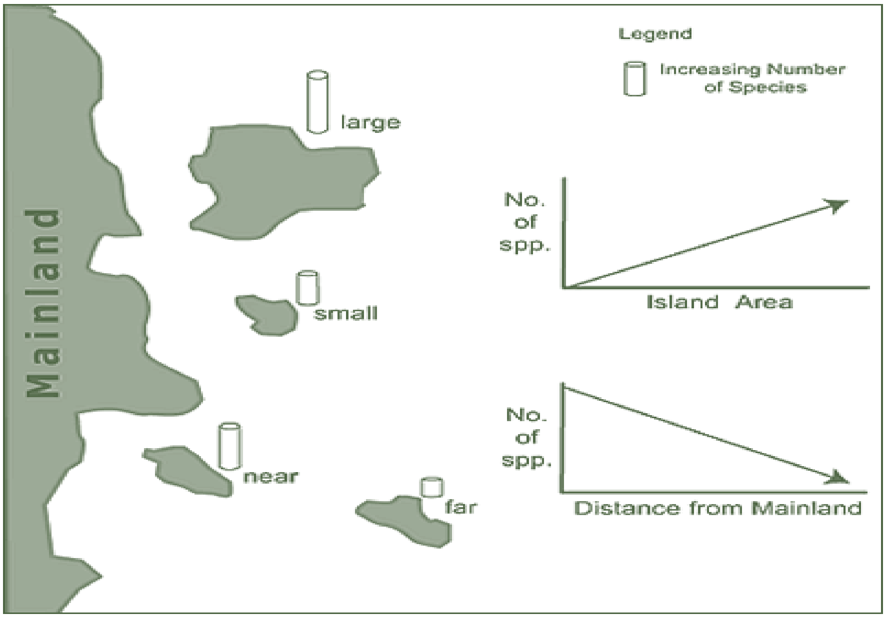
Practical Considerations

- Effect of island size
- Effect of island distance





Island Biogeography Theory

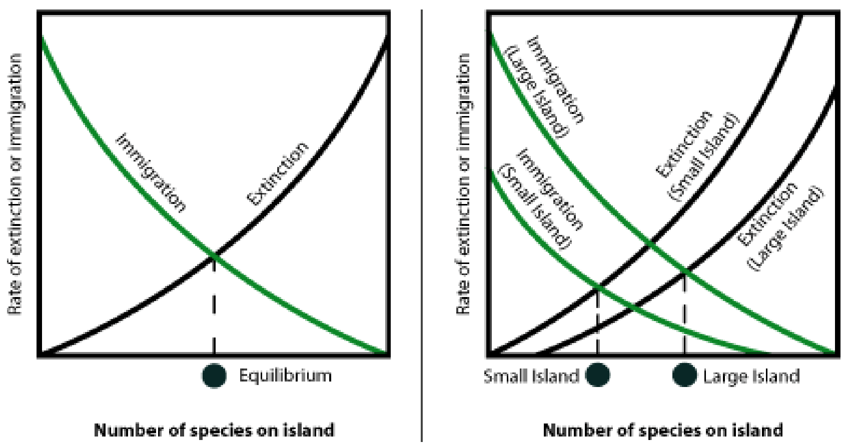


Island Biogeography Theory

- The number of species on an island is determined by the rate of immigration of new species and the rate of local extinction.
- Immigration is arrival of new species from mainland—larger patch.
- As the number of species on an island increases immigration rate declines
  - Niches are filled.
- As more species take up space, the population size of each species decreases.
  - Islands can hold a fixed number of species.
  - More likely go extinct
  - Extinction rate increases.

Island Biogeography Theory

- The number of species reaches a steady-state.
  - Immigration rate equals to extinction rate.

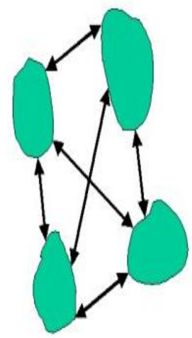


Metapopulation Theory

- Proposed by Levin (1970).
- Metapopulation (population of populations) is a group of several local populations that are linked by immigration and emigration.
- Theory similar to Island Biogeography
  - Populations instead of species
  - Think of a population as an island
- Population size is a result of
  - Immigration and emigration of genes.
- Smaller populations more prone to extinction.
- Local (sink) populations can go extinct but can be repopulated by source populations.

Metapopulation Theory

- Emphasizes the importance of connectivity between seemingly isolated populations.
  - Reducing migration potentially leads to local extinction of species over a wider area.
- Destruction of source populations might lead to extinction of many smaller populations.



- Habitat occurs in discrete patches
- All populations have a substantial risk of extinction
- Dispersal occurs among all patches
- Patch dynamics are asynchronous
- **Ignore population dynamics within a patch**

Conservation and Reserve Design

- Protect the greatest number of species, populations and ecosystems.
- Time and money are always limiting
  - Maximize benefits through ecological knowledge.
- Single large or several small reserves?
  - Which is better?

In a nutshell

(Anning's Take on the Need for Conservation)

- Conservation is a response to a global environmental crisis that requires an immediate action.
  - Rapid human population expansion has led to unprecedented and unsustainable rates of natural resource consumption.
  - Humans activities continue to directly and indirectly deplete natural resource and threaten biodiversity, fast driving a number of them into extinction.
  - Human wellbeing and survival are directly linked to the sustenance of biodiversity.
  - It is our responsibility to safeguard natural resources (biodiversity) for future generations.

End!!!