UNIT 3: HOW CAN BIODIVERSITY AND DEVELOPMENT BE SUSTAINED

AREA OF STUDY 1: IS MAINTAINING BIODIVERSITY WORTH A SUSTAINED EFFORT?

Key knowledge

Importance of biodiversity

"Biodiversity is the collective term for the full variety of life on earth. Many think of it as the total number of species, but it is actually more complex than that. It's about the genetic diversity within species, the diversity of habitats, and the large biological units known as biomes."

UN Foundation Senior Fellow, Dr. Thomas Lovejoy, who is credited with being the first to use the term "biological diversity"

the definition and categories of biodiversity (genetic, species and ecosystem)

Biodiversity includes:

- ✓ diversity within species (genetic diversity)

  Genetic diversity - The variety of different types of genes in a species or population.

  The gene is the basic unit of inheritance. Low genetic diversity means the population has a low capacity to cope with environmental change. Greater genetic diversity, the greater a species chance of survival

- ✓ diversity between species (species diversity)

  Species diversity – the number of different species AND the number of individuals within each species. A **species** is defined as a group of organisms that can interbreed to produce fertile offspring.

  Species diversity;

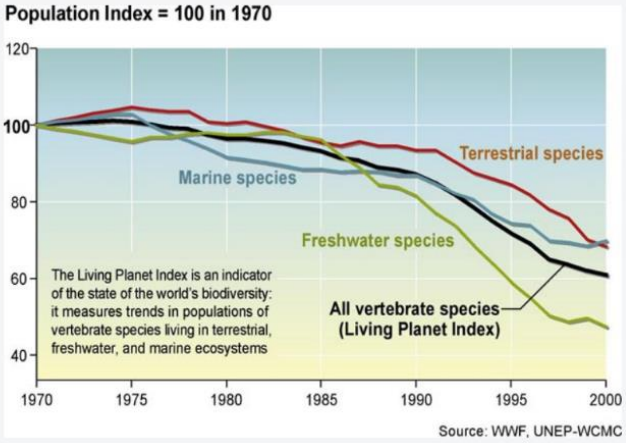
  - generally, decreases as you move from the equatorial regions to the poles.
  - generally, decreases with altitude

- ✓ diversity between ecosystems (ecosystem diversity)

  Ecosystem diversity – the variety of habitats, niches, communities and ecological processes

Figure 3.7. The Living Planet Index, 1970–2000

The index currently incorporates data on the abundance of 555 terrestrial species, 323 freshwater species, and 267 marine species around the world. While the index fell by some 40% between 1970 and 2000, the terrestrial index fell by about 30%, the freshwater index by about 50%, and the marine index by around 30% over the same period.



the importance of genetic diversity within a species or population in withstanding changes in environmental selection pressures that will either confer an advantage (adaptation) or disadvantage for a particular genetic trait (excluding mechanisms of gene function)

see Genetic diversity defn above - Low genetic diversity means the population has a low capacity to cope with environmental change. Greater genetic diversity, the greater a species chance of survival

ecosystems as a source of renewable services that impact on human well-being including provisioning services (food, water, pharmaceuticals), regulating services (carbon sequestration, climate control), and supporting services (soil formation, nutrient and water recycling, air and water purification)

Ecosystem services are the benefits obtained by people from ecosystems. These include:

- ✓ *provisioning services* – ecosystems providing basic materials/resources

  food, clean water, timber, fibre, fuel, biochemical and genetic resources

- ✓ *regulating services* – ecosystems regulating natural processes, *such as the regulation of climate, floods, disease, water quality, and pollination*

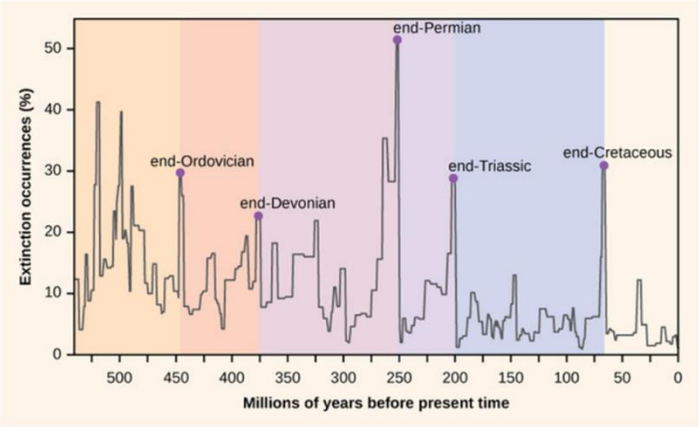
- ✓ *cultural services* – ecosystems providing recreational, aesthetic, and spiritual benefits

- ✓ *supporting services* – ecosystems supporting natural processes such as;

  soil formation, nutrient cycling, invasion resistance, pollination, seed dispersal, hazard protection, sequestration.

Biodiversity change over time

evidence of variation in rate and extent of change in biodiversity over time including significant mass extinctions and periods of rapid species diversification that can be inferred from the fossil record



✓ Mass extinctions are periods in Earth's history when abnormally large numbers of species die out simultaneously or within a limited time frame.

✓ A series of mass extinction events have occurred throughout the history of the Earth.

✓ The most severe occurred at the end of the Permian period when 96% of all species perished.

the impact of humans on the present rate of species extinction

Human activity has been causing massive extinctions;

The International Union for Conservation of Nature (IUCN) notes that many species are threatened with extinction. In addition,

At threat of extinction are

- ✓ 1 out of 8 birds
- ✓ 1 out of 4 mammals
- ✓ 1 out of 4 conifers
- ✓ 1 out of 3 amphibians
- ✓ 6 out of 7 marine turtles
- ✓ 75% of genetic diversity of agricultural crops has been lost
- ✓ 75% of the world's fisheries are fully or over exploited
- ✓ Up to 70% of the world's known species risk extinction if the global temperatures rise by more than 3.5°C
- ✓ 1/3rd of reef-building corals around the world are threatened with extinction
- ✓ Over 350 million people suffer from severe water scarcity

As explained in the UN's 3rd Global Biodiversity Outlook8, the rate of biodiversity loss has not been reduced because the 5 principle pressures on biodiversity are persistent, even intensifying:

- ✓ Habitat loss and degradation
- ✓ Climate change
- ✓ Excessive nutrient load and other forms of pollution
- ✓ Over-exploitation and unsustainable use
- ✓ Invasive alien species

the isolation of populations over short (volcanic eruptions or fire), medium (El Nino) and long (tectonic plate movement and evolution) time scales that can produce different species that are unable to interbreed, are endemic to a location, form a diversity hotspot, or become extinct, including explanation of why some ecosystems are more diverse than others.

- ✓ Ecosystems are dynamic and change over time. Today's ecosystems have been influenced by changes over various time frames;
  - short term (volcanic eruptions or bush fire),
  - medium term (El Nino)
  - long term (tectonic plate movement and evolution)

  These changes can result in favourable and unfavourable consequences.

- ✓ *Geographic isolation* –when some members of a species become cut off from the rest of the species. A new species might form when a group of individuals remains separated from the rest of its species long enough to accumulate different traits
- ✓ *Biodiversity hot spot* – areas where native species and communities are well represented with high diversity and many endemic species (*endemic* – species not found outside that area/hotspot)

  Eg Victorian Western Volcanic Plains

  - Fertile volcanic soils
  - Large shallow lakes

Measuring changes in biodiversity

sampling methods used for assessing species diversity including grids, transects, different shaped quadrats (including consideration of edge effects), and mark-recapture

In a scientific investigation, the factors that can change are known as variables. In order for a scientific investigation to be fair and valid only one variable can be changed at any one time. If more than one variable is changed, the effect cannot be linked to a single variable and the cause of the change is still unknown.

To ensure a fair or valid test, variables must be set appropriately;

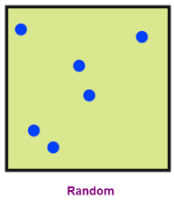
- The controlled variables are the factors that must be kept the same for all trials in an investigation to ensure fair and valid results.
- The independent variable is the factor that you change to measure the effect.
- The dependent variable is the factor you measure.

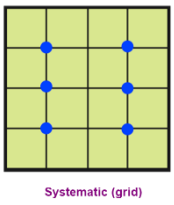
Reliability is achieved by establishing a detailed procedure or experimental method. Reliability of an experiment is achieved by;

- Having a clearly defined experimental procedure
- Repeating the procedure several times to confirm consistency in results
- Collecting as much data as feasible for the scope of the experiment.

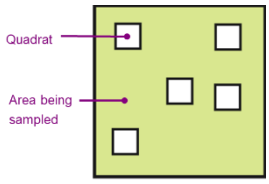
Experimental accuracy considered the precision of any data collected or measurements made. Accuracy is enhanced by the rigor with which the experimental design is followed and the quality of the instruments recording the data.

Different sampling techniques are suited to different organisms (life forms) in an ecosystem when predicting population numbers. The method selected will depend on the type of organism you are studying.

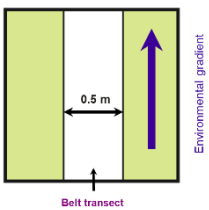


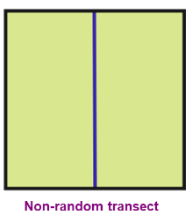


Point sampling is a technique where individual points are chosen on a map (using a grid reference or random numbers applied to a map grid) and the organisms are sampled at those points. Point sampling is time efficient and useful in establishing species abundance or community compositions.



✓ *Quadrat sampling* is a method by which organisms in a certain set proportion (sample) of the habitat are counted or measured directly. Quadrats are used when the populations sedentary or slow moving and are too large to count in their entirety. Quadrats may be used without a transect when studying a relatively uniform habitat.





✓ Transects may be used to relate patterns of zonation to environmental factors. Two types of transect may be used: *Line transects* are drawn across a map, and organisms occurring along the line are sampled. *Belt transects* are basically a form of continuous quadrat sampling.

✓ *Mark and recapture* is used to determine the total population density for highly mobile species in a certain area. The measure is calculated to determine the Lincoln Index;

Lincoln Index:

N1 x N2 / N3 = Population estimate

Number of animals captured and marked / tagged (N1)
Number of recapture animals (N2)
Number caught which are marked from first capture (N3)

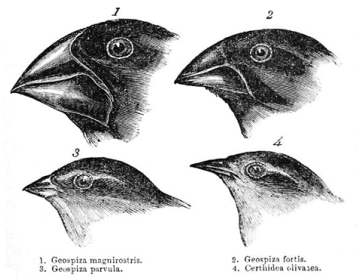
assessment of genetic diversity through variations in morphology as an indicator of genetic make-up of individuals within a species

Genetic diversity is the total number of genetic characteristics in the genetic makeup of a species. It is different from genetic variability, which describes the how genetic characteristics may vary.

Genetic diversity is important for two reasons.

First of all, with more variation, it is more likely that some individuals in a population will possess variations of alleles (variation within a specific gene) that are suited for the environment. Those individuals are more likely to survive to produce offspring bearing that allele. The population will continue for more generations because of the success of these individuals. Darwin termed this process "natural selection" and famous work with finches on the Galapagos' Islands demonstrates this property.

Morphology refers to how the appearance of the individual reflects the genetic diversity, which was central to Darwin's Finches.



measurement of species diversity, including species richness, endemism and species diversity, and the application of simple indices, including Simpson's Index

✓ *Species Richness*

The number of species per sample is a measure of richness. The more species present in a sample, the 'richer' the sample.

Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species which have very few individuals as to those which have many individuals. Thus, one daisy has as much influence on the richness of an area as 1000 buttercups.

✓ *Species Diversity*

Species Diversity (aka Evenness) is a measure of the relative abundance of the different species making up the richness of an area.

	Numbers of individuals	
Flower Species	Sample 1	Sample 2
Daisy	300	20
Dandelion	335	49
Buttercup	365	931
Total	1000	1000

Both samples have the same richness (3 species) and the same total number of individuals (1000).

However, the first sample has more species diversity than the second. This is because the total number of individuals in the sample is quite evenly distributed between the three species. In the second sample, most of the individuals are buttercups, with only a few daisies and dandelions present. Sample 2 is therefore considered to be less diverse than sample 1.

✓ *Simpson's Diversity Index* is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species.

$$Simpson's\ Index: D = 1 - \frac{\sum[n_i(n_i - 1)]}{N(N-1)}$$

note: Σ refers to the 'sum of'

n_i means the total number of organisms of each individual species

N means the total number of organisms of all species

Simpson's Index values range from 0 – 1. A higher index indicates a greater species diversity. The Simpson Index for the sample below

= 1 – 36/182

= 0.80

Species found in stream sample	n_i	$n_i - 1$	$n(n_i - 1)$
Caddisfly	4	4 - 1 = 3	4 x 3 = 12
Mayfly	1	0	0
Stonefly	0	-1	0
Riff Beetle	0	-1	0
Gill Snail	0	-1	0
Dodsonfly	2	1	2
Crane Fly	1	0	0
Dragonfly	2	1	2
Midge	5	4	20
N =	*14*		$\sum[n_i(n_i - 1)] = 36$
N(N-1)	*14 (14 - 1) = 182*		

the measures of ecosystem diversity including the number of different ecosystems in a biosphere and the variety of ecological processes that occur in different physical settings

Levels of biodiversity in an area can be assessed in a variety of ways;

- Species richness
- Species diversity
- Simpson's Index
- Degree of endemism: Endemism is the percentage of endemic species in an ecosystem
- Vegetation structure: type, age, environmental conditions, adaptively

Phylum	% Endemism in Australia
Vascular plants	91.8
Mammals	87
Birds	45
Reptiles	93
Amphibians	94
Invertebrates	unknown

conservation classification of species and how this depends on measures including changes in the geographic range and number of individuals within that range, the date the species was last recorded, and the extent of habitat.

When classifying the risk of a particular species 5 criteria used to classify a species as at risk including:

- A substantial *rate of decline* (observed, inferred, or projected).
- A small *geographical range* that is shrinking or is projected to shrink.
- A small *population size* that is either single, or fragmented into isolated subpopulations.
- A strong *probability of extinction* within a specified time period, revealed by a quantitative analysis of population viability.
- A specific *habitat risk* to the species.

Population trait	*Vulnerable*	*Endangered*	*Critical*
Observed decline	20% in 10 yrs or 3 generations	50% in 10 yrs or 3 generations	80% in 10 yrs or 3 generations
Geographical range	< 20 000 km² < 10 locations	< 5000 km² < 5 locations	< 100 km² single location
Total population N = population size N_s = subpopulation sizes	N < 10 000 N_s < 1000	N < 2500 N_s < 250	N < 250 N_s < 50
Projected decline	> 20% in 10 yrs or 3 generations	> 20% in 5 yrs or 2 generations	> 25% in 3 yrs or 1 generation
Probability of extinction	> 10% in 100 yrs	> 20% in 20 yrs or 5 generations	> 50% in 10 yrs or 3 generations

Threats to biodiversity

predictions of species population survival using probabilities including likelihood of extinction

Population viability analysis is a technique that assists management and conservation. Mathematical models can incorporate ecological data (population, age, structure, birth and death rates, migration and symbiotic factors) to predict the likelihood of extinction for a particular species. These models can also assess the impact of predicted threats.

These models help scientists foresee how a population is likely to react to changes in the environment and therefore how likely it is to die out.

Scientist may use a simplified probability analysis when more than one population of a species is assessed;

Eg Location 1 - 40% probability of extinction in the next 10 years

Location 2 - 70% probability of extinction in the next 10 years

Overall probability = Pr (Location 1) x Pr (Location 2)

= 0.4 x 0.7

= 0.28

Species has a 28% probability of extinction in the next 10 years

human and non-human threats to biodiversity including: creation and isolation of small populations through habitat modification and over-exploitation; genetic swamping, inbreeding, and demographic variation due to small population size; loss of pollinators, dispersal agents, host species or symbionts that affect reproduction and persistence of species; bioaccumulation that concentrates environmental poisons in food chains; and exotic species that compete for habitat, shelter and food

Extinction is a natural process that is part of the life cycle of a species. There has been a rapid increase in extinction rates as a result of human activity. Scientists estimate that human destruction of natural habitat is driving up to 100 000 species to extinction every year.

This recent acceleration in species loss is sometimes called the ***sixth extinction***.

Threats to biodiversity including:

- Reduced population size
- Genetic drift (*when genetic variability within a population is altered by random events rather than natural selection.*
- creation and isolation of small populations through habitat modification and over-exploitation
- (i) genetic swamping (*when a small interbreeding population contacts a larger population, the genes from a larger population can spread through the smaller population)*,

  (ii) Inbreeding *(small populations interbreed easily resulting in reduced survival rates and reproductive success and lack of population richness)*, and

  (iii) Demographic variation *(a chance variation in the birth rate, death rate or sex ratio within a population over time)*
- loss of pollinators, dispersal agents, host species or symbionts that affect reproduction and persistence of species
- bioaccumulation that concentrates environmental poisons in food chains
- exotic species that compete for habitat, shelter and food.

assessment of threat in defining conservation categories for a species and/or ecosystem, including extinct in the wild, conservation dependent, critically endangered, endangered, and vulnerable.

International Union for Conservation of Nature's (IUCN) *Red List of Threatened Species* has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungus and plant species. Species are classified by the IUCN Red List into nine groups;

- Extinct (EX) – beyond reasonable doubt that the species is no longer extant.
- Extinct in the wild (EW) – survives only in captivity, cultivation and/or outside native range, as presumed after exhaustive surveys.
- Critically endangered (CR) – in a particularly and extremely critical state.
- Endangered (EN) – not critically endangered but facing high risk of extinction in the near future.
- Vulnerable (VU) – meets one of the 5 red list criteria and thus considered to be at high risk of unnatural (human-caused) extinction without further human intervention.
- Near threatened (NT) – close to being at high risk of extinction in the near future.
- Least concern (LC) – unlikely to become extinct in the near future.
- Data deficient (DD)
- Not evaluated (NE)

Protection and restoration of biodiversity

strategies for maintaining and growing populations that also build species resilience to changes in the environment, including: protected areas; retaining remnant vegetation; wildlife corridors or zones; translocation of animals; habitat regeneration,

restoration or replacement; captive breeding and reintroduction programs; gene banks for the collection of specimens and genetic material; and reduction and improved targeting of pesticides in agricultural and urbanised areas

Various management strategies are used to protect species at risk and help threatened species to return to sustainable population sizes.

These management strategies are used worldwide and include:

- *protected areas*
- *retaining remnant vegetation*
- *wildlife corridors or zones*
- *translocation of animals*
- *habitat regeneration, restoration or replacement*
- *captive breeding*
- *reintroduction programs*

the application of relevant international, national, state and local legal treaties, agreements and regulatory frameworks that apply to the protection of threatened species including the Convention on International Trade in Endangered Species (CITES), IUCN Red List of Threatened Species, World Heritage areas, Environment Protection and Biodiversity Conservation Act 1999 (Australia), Victorian Flora and Fauna Guarantee Act, and local government conservation covenants

Various mechanisms have been put in place, at both international and domestic levels, to protect and preserve biodiversity including;

- International conventions
- Treaties
- Agreements and recommendations
- Domestic acts and policies

CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international *agreement* between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

The IUCN Red List provides *information* about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions. It is used by government agencies, wildlife departments, conservation-related non-governmental organisations (NGOs), natural resource planners, educational organisations, students, and the business community.

United Nations Educational, Cultural and Scientific Organisation (UNESCO) seeks to build peace through *international cooperation* in Education, the Sciences and Culture. UNESCO's programmes contribute to the achievement of the Sustainable Development Goals defined in Agenda 2030, adopted by the UN General Assembly in 2015.

Australian legislation provides *clear rules* to ensure the conservation of biodiversity including:

- Environmental protection and biodiversity conservation act 1999 (Commonwealth)
- Flora and Fauna Guarantee Act 1988 (VIC)
- Victorian Biodiversity Strategy 1997 (VIC)
- Local government planning laws

Legislation provided legal protection under these laws!

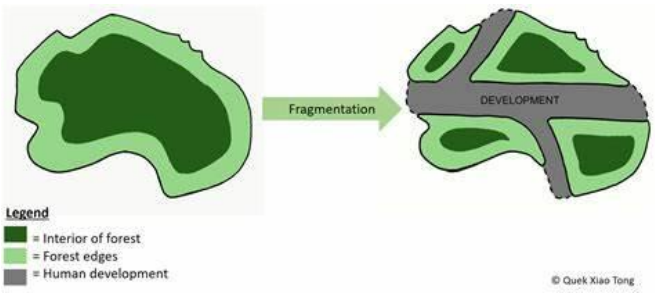
sustainability principles relevant to biodiversity conservation including: inter- and intra-generational equity including funding of selected species; the precautionary principle in relation to habitat change or introduction of species; ethical principles for managing biodiversity including justice and beneficence; and value systems including anthropocentrism, biocentrism and ecocentrism.

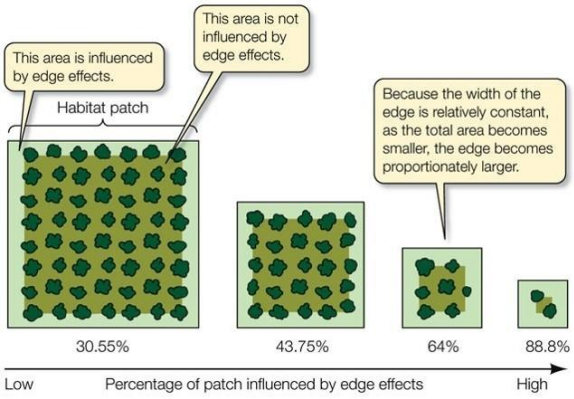
Anthropocentrism – a belief that humans are the central and most significant species on the planet.

Biocentrism – a belief that all life is equal in importance.

Ecocentrism – a perspective that places important on the natural ecology rather than individual species.

Habitat edge effect - In ecology, edge effects are changes in population or community structures that occur at the boundary of two or more habitats. Areas with small habitat fragments exhibit especially pronounced edge effects that may extend throughout the range. As the edge effects increase, the boundary habitat allows for greater biodiversity.


Fragmentation
DEVELOPMENT
Legend
= Interior of forest
= Forest edges
= Human development
© Quek Xiao Tong


This area is influenced by edge effects.
This area is not influenced by edge effects.
Habitat patch
Because the width of the edge is relatively constant, as the total area becomes smaller, the edge becomes proportionately larger.
30.55%
43.75%
64%
88.8%
Low
Percentage of patch influenced by edge effects
High