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 its role in biodiversity loss
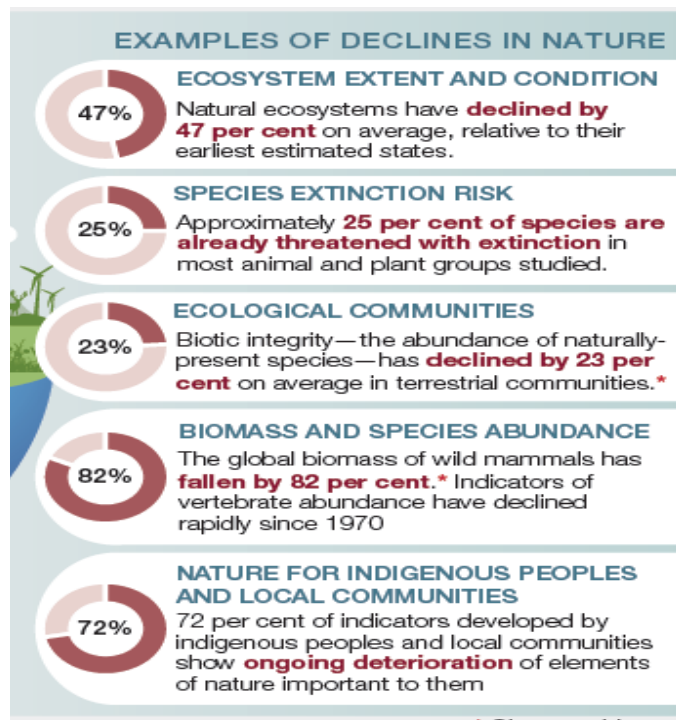
Trends in Global Biodiversity Change

- 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)

EXAMPLES OF DECLINES IN NATURE

ECOSYSTEM EXTENT AND CONDITION
47% — Natural ecosystems have **declined by 47 per cent** on average, relative to their earliest estimated states.

SPECIES EXTINCTION RISK
25% — Approximately **25 per cent of species are already threatened with extinction** in most animal and plant groups studied.

ECOLOGICAL COMMUNITIES
23% — Biotic integrity—the abundance of naturally-present species—has **declined by 23 per cent** on average in terrestrial communities.*

BIOMASS AND SPECIES ABUNDANCE
82% — The global biomass of wild mammals has **fallen by 82 per cent.*** Indicators of vertebrate abundance have declined rapidly since 1970

NATURE FOR INDIGENOUS PEOPLES AND LOCAL COMMUNITIES
72% — 72 per cent of indicators developed by indigenous peoples and local communities show **ongoing deterioration** of elements of nature important to them

* Since prehistory

2

Global Biodiversity Change

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

3

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

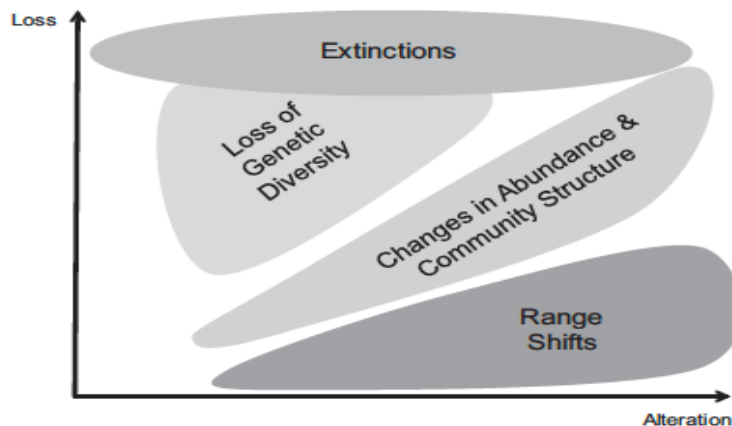- About 40% of the oceans have been affected by several drivers

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.
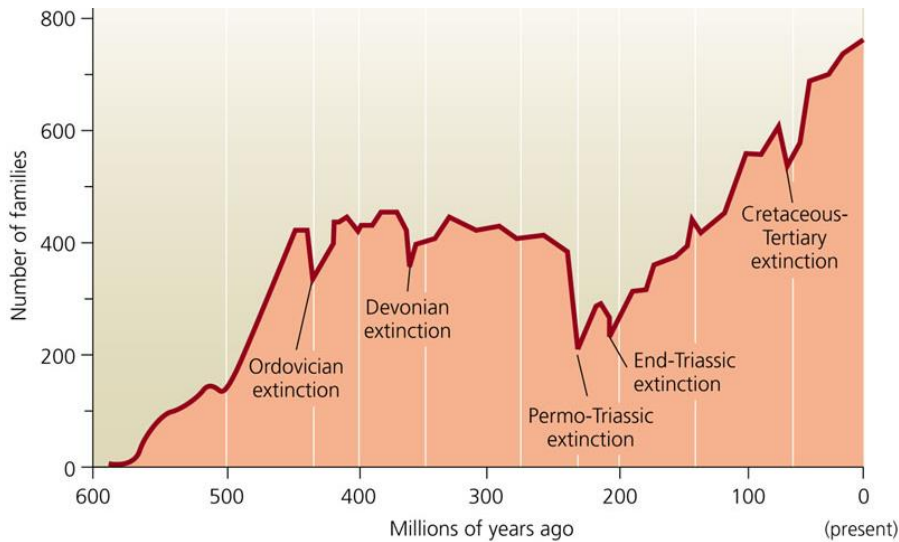
Pereira et al. 2012

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).
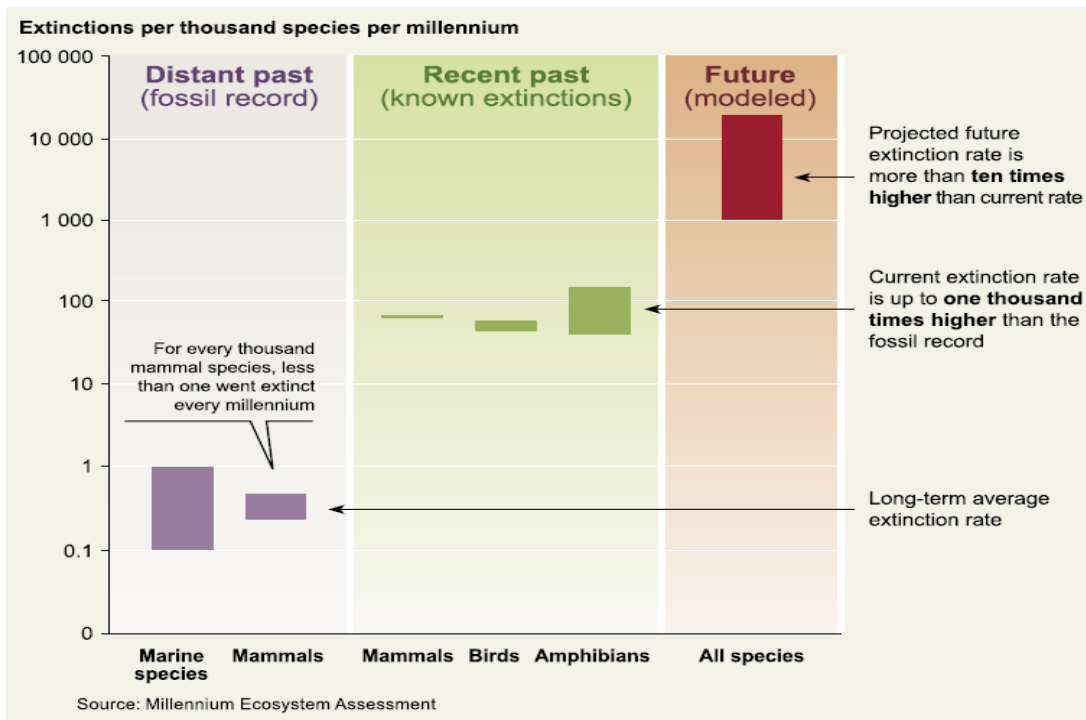
Extinction

- 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.
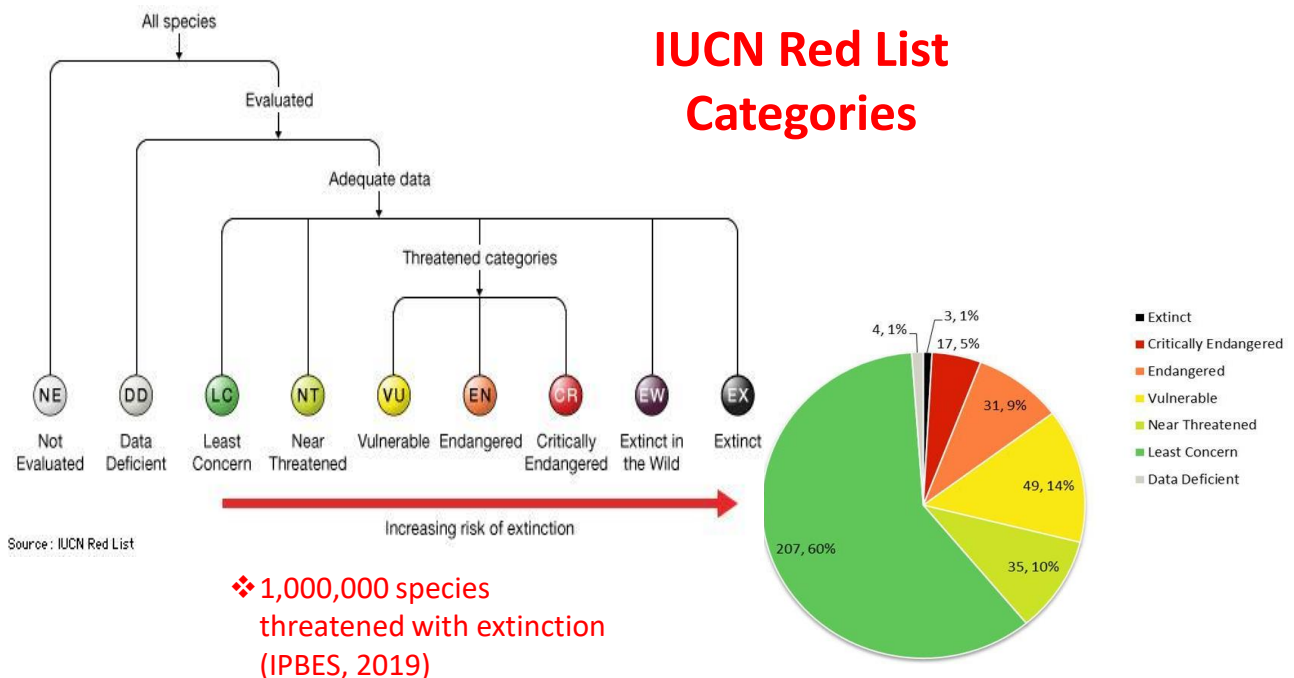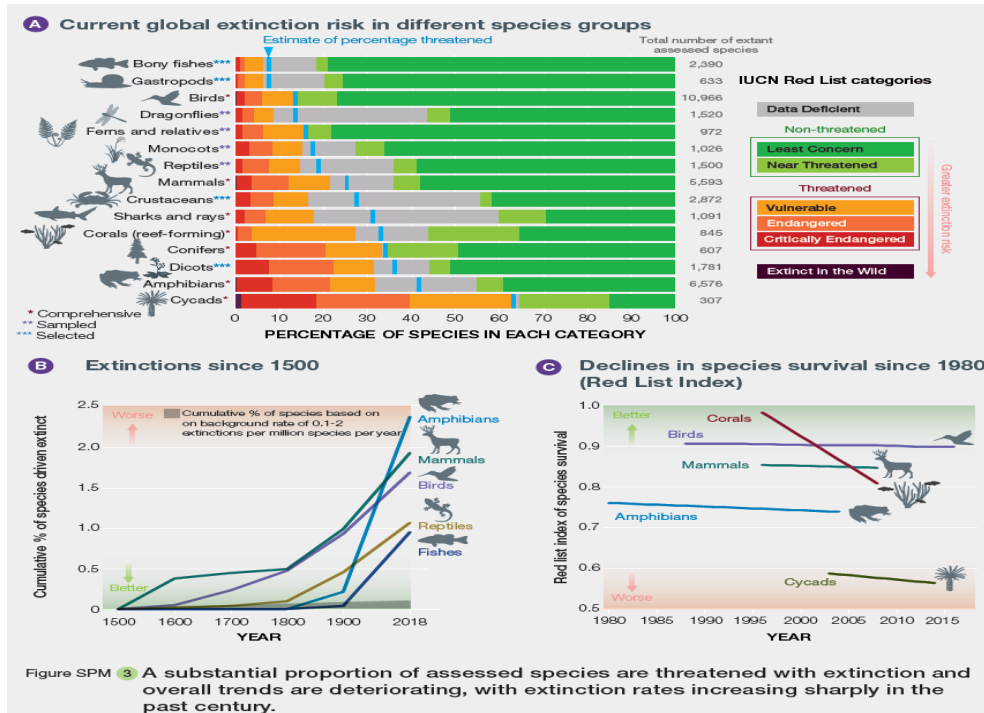
Mass extinctions

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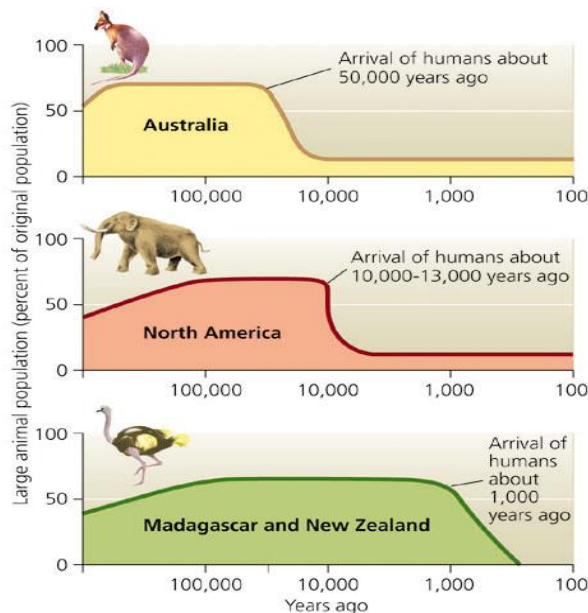
Today's mass extinction

- 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

All species

Evaluated

Adequate data

Threatened categories

NE	DD	LC	NT	VU	EN	CR	EW	EX
Not Evaluated	Data Deficient	Least Concern	Near Threatened	Vulnerable	Endangered	Critically Endangered	Extinct in the Wild	Extinct

Increasing risk of extinction

Source : IUCN Red List

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

- Extinct — 4, 1%
- Critically Endangered — 17, 5%
- Endangered — 31, 9%
- Vulnerable — 49, 14%
- Near Threatened — 35, 10%
- Least Concern — 207, 60%
- Data Deficient — 3, 1%

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.
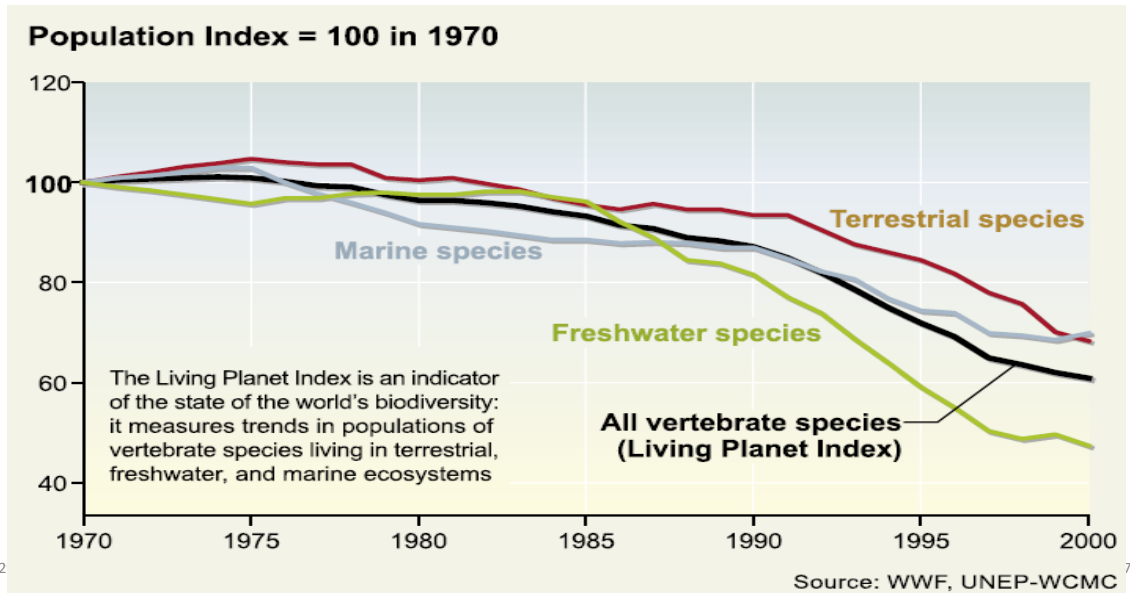
Today's mass extinction

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

Population Index = 100 in 1970

The Living Planet Index is an indicator of the state of the world's biodiversity: it measures trends in populations of vertebrate species living in terrestrial, freshwater, and marine ecosystems

Source: WWF, UNEP-WCMC

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."*
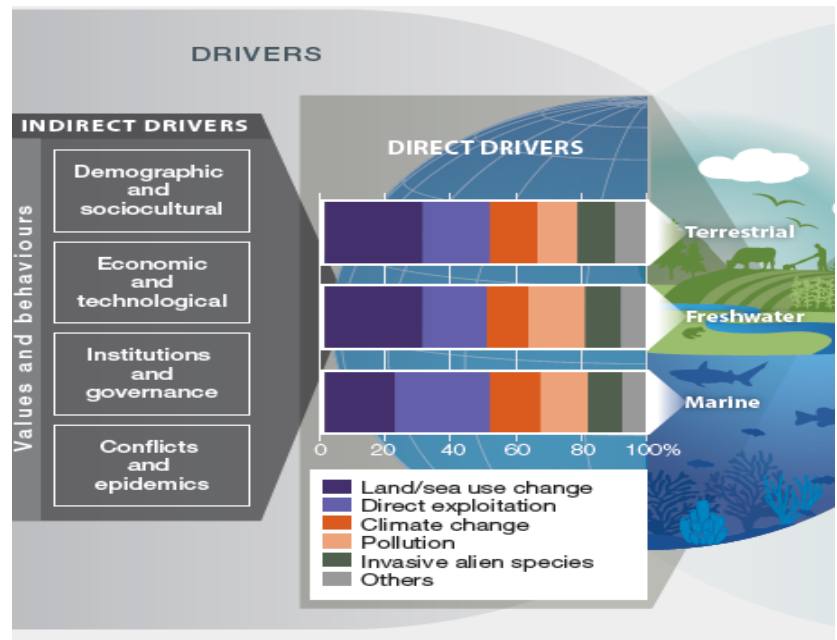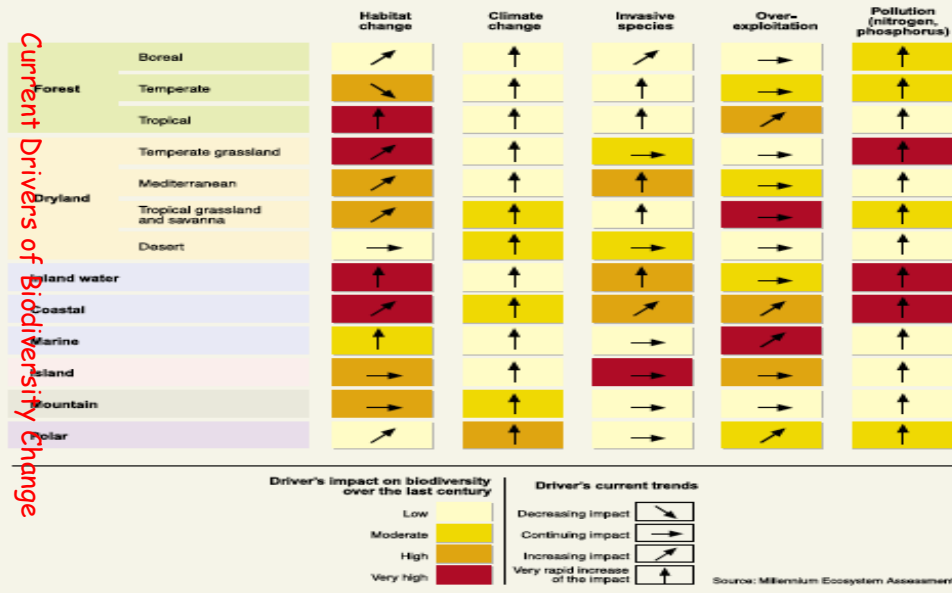
— E. O. Wilson, 1985

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.

Current Drivers of Biodiversity Change
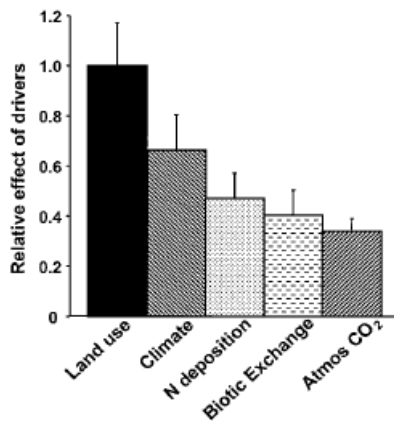
Drivers of Biodiversity Change in 2100?

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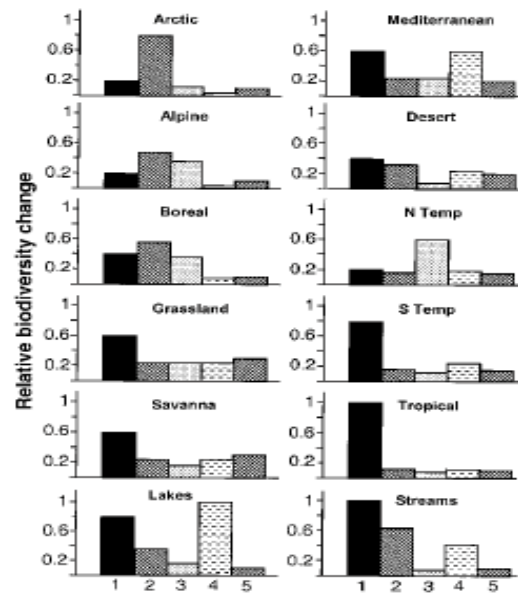
Fig. 2. Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of

Sala et al. 2000

Which ecosystems will be most affected in 2100?

NO interactions (SUM)
MED (1.00)
GRAS (0.90)
SAV (0.82)
BOR (0.80)
S.TEMP (0.78)
TROP (0.76)
N.TEMP (0.69)
ARCT (0.67)
DESERT (0.66)

Antagonistic interactions (MAX)
TROP (1.00)
ARCT (0.80)
S.TEMP (0.80)
GRAS (0.60)
SAV (0.60)
MED (0.60)
N.TEMP (0.60)
BOR (0.56)
DESERT (0.40)

Synergistic interactions (MULT)
MED (1.00)
GRAS (0.50)
SAV (0.40)
BOR (0.16)
S.TEMP (0.13)
N.TEMP (0.13)
DESERT (0.12)
TROP (0.03)
ARCTIC (0.02)
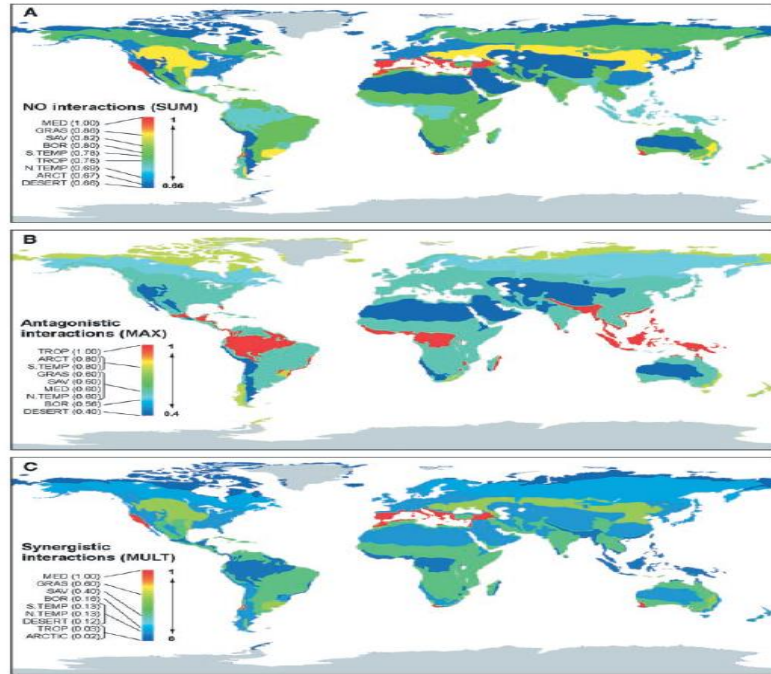
Sala et al. 2000

29-May-23

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

Anthropogenic climate change

Pollution

Island invasions

Agriculture and forest clearing

Fishing

Hunting

Fire

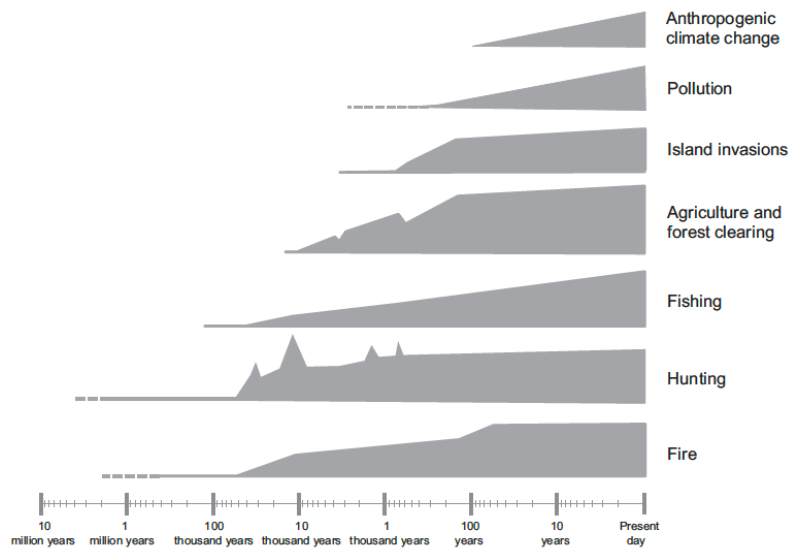| 10 million years | 1 million years | 100 thousand years | 10 thousand years | 1 thousand years | 100 years | 10 years | Present day |

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).

29-May-23

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.

© Chris Ransom

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.
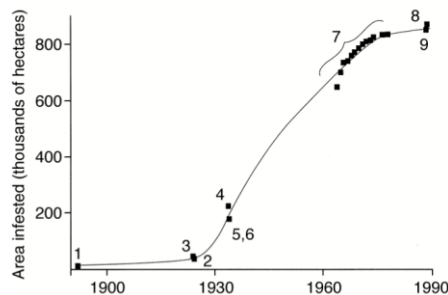
Invasive Species

- 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.
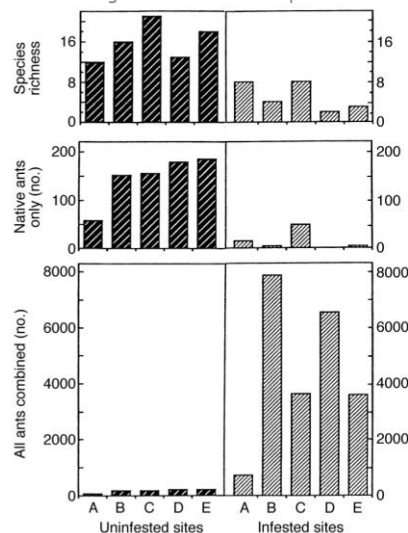 - Control costs runs into billions of dollars.

Kudzu

Rana frog

Zebra mussel

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
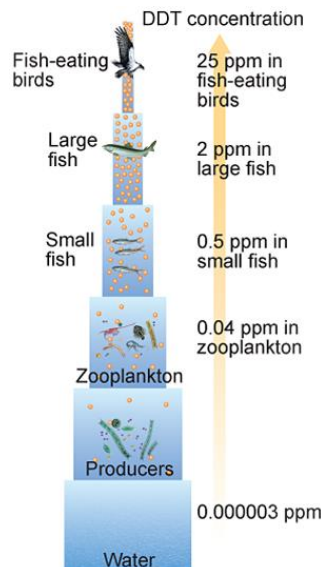
Mack *et al*. 2000

Pollution

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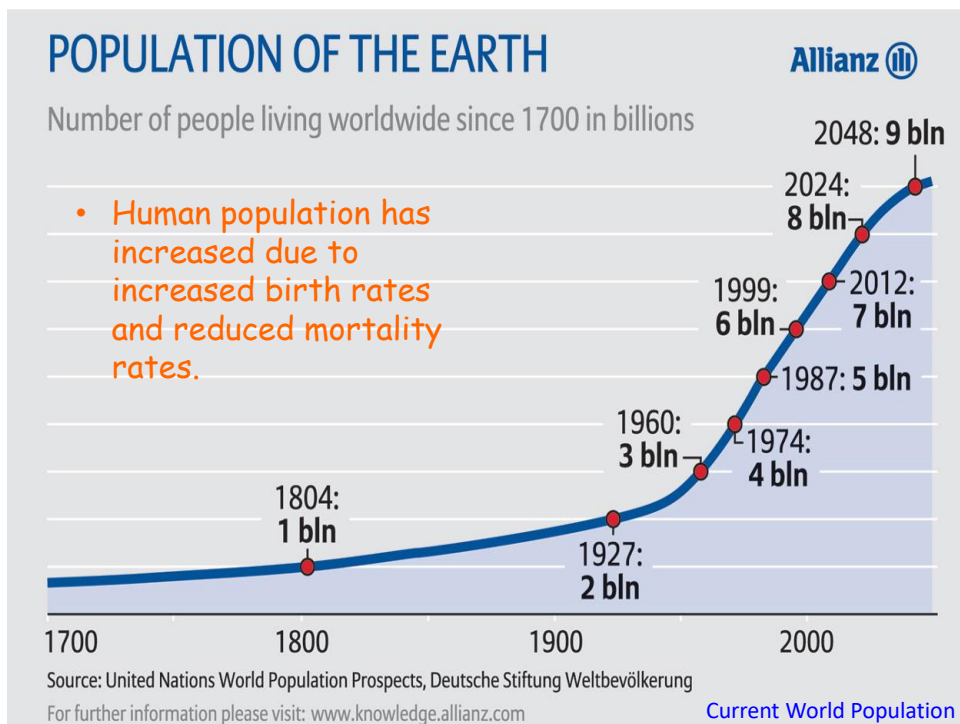
Pollution

- **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.

DDT concentration

Fish-eating birds — 25 ppm in fish-eating birds

Large fish — 2 ppm in large fish

Small fish — 0.5 ppm in small fish

Zooplankton — 0.04 ppm in zooplankton

Producers

Water — 0.000003 ppm

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.
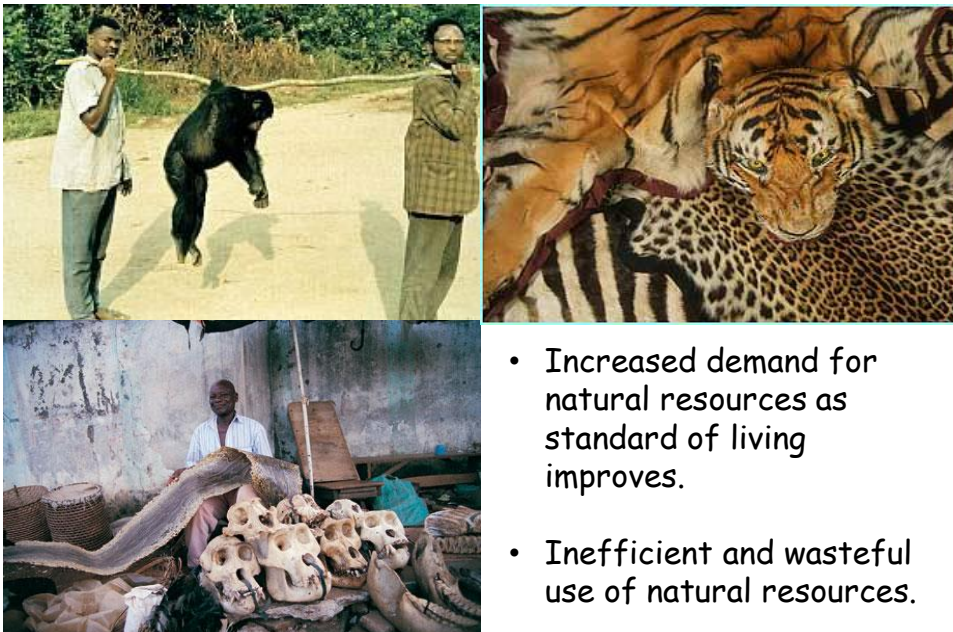
POPULATION OF THE EARTH

Allianz

Number of people living worldwide since 1700 in billions

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

2048: **9 bln**

2024: **8 bln**

2012: **7 bln**

1999: **6 bln**

1987: **5 bln**

1974: **4 bln**

1960: **3 bln**

1927: **2 bln**

1804: **1 bln**

1700   1800   1900   2000

Source: United Nations World Population Prospects, Deutsche Stiftung Weltbevölkerung

For further information please visit: www.knowledge.allianz.com

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.

BIOL 452 Biodiversity Conservation & Utilization   Gaston, 2010   35