Ecological Principles and Biodiversity for Sustainability

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9. Community changes and ecological succession

Community

"A group or association of populations of two or more different species occupying the same geographical area and in a particular time"

A community

(Ankur Awadhiya 2018 Manas TR)

What is an ecotone?

"A transition area where two communities meet and integrate"

It may be sharp or diffuse.

Community characteristics

1. Species diversity: Which species are living together?
2. Growth form and structure: trees, shrubs, herbs, mosses and vertical stratification.
3. Dominance: Dominant species are those that are "highly successful ecologically and which determine to a considerable extent the conditions under which the associated species must grow."
4. Relative abundance: The relative proportions of different species in the community.
5. Trophic structure: Who eats whom?

Community description

1. Species richness: number of species
2. Species abundance: in terms of number of individuals, biomass or cover
3. Species dominance: ranking as per abundance (number, basal area, etc.)

Some definitions

$$\text{Relative density} = \frac{\text{Number of individuals of species x}}{\text{Total individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of species x}}{\text{Sum of frequency values for all species}} \times 100$$

where frequency is defined as the probability of finding the species in any one quadrat

$$\text{Relative dominance} = \frac{\text{Basal area of species x}}{\text{Total basal area of all species}} \times 100$$

Importance value

Importance value of species x

= Relative density + Relative frequency + Relative dominance

Importance value ranges from 0 to 300.

Guilds

A guild is a group of species which utilise resources in a similar way[1].

e.g. a group of fruit eating birds in a rainforest, a guild of forest-floor dwelling herbs, etc.

Because species within a guild utilise the same resources, so we expect them to compete more strongly with each other than with species from other guilds.

[1]Root, R.B., 1967. The niche exploitation pattern of the blue-gray gnatcatcher. Ecological monographs, 37(4), pp.317-350.

Niche

"The ecological niche of a species is a multidimensional description of its resource needs, habitat requirements and environmental tolerances."

1. Fundamental niche: "the potential set of conditions which a species can occupy"
   It is determined experimentally.
   Also known as precompetitive niche.
2. Realised niche: "the set of conditions which a species actually occupies due to effects of competition, predation, etc."
   It is determined through field observations.
   Also known as postcompetitive niche.

Characteristics of niches

1. Fundamental niche $\geq$ Realised niche.
2. Realised niche for populations of the same species may differ because of difference in extant conditions at the two locations.
3. Specialist species have narrow niches, generalist species have broad niches.
4. The fundamental niche elaborates on the various roles of species. The realized niche elaborates on what the species actually do.
5. Species are well adapted to their realised niches.

Index of similarity

Consider two communities, one with a number of species, and another with b number of species. If there are c species that occur in both the communities, we have

$$\text{Index of similarity} = \frac{2c}{a+b}$$

Association of a species with community[2]

1. Accidental species: rare species in the community, present either as chance invaders from another community or as relicts from a previous community
2. Indifferent species: a species with no real affinity for any particular community, but which is not rare
3. Preferential species: a species that is present with varying abundance in several communities, but is especially abundant and vigorous in one particular community
4. Selective species: a species found most frequently in a particular community, but also present occasionally in others
5. Exclusive species: a species that is confined completely or almost completely to a particular community

[2] Blanquet, B. and Pflanzensoziologie, J., 1964. Grudzuge der Vegetationskunde.

Community stability

1. stability: the ability of a community to recover following a disturbance
2. resistance: the ability of the community to persist without change (loss of species) in the face of disturbance
3. resilience: the speed at which the community recovers following disturbance

Ecological succession

Bare rocks

(Ankur Awadhiya 2014 Mussoorie)

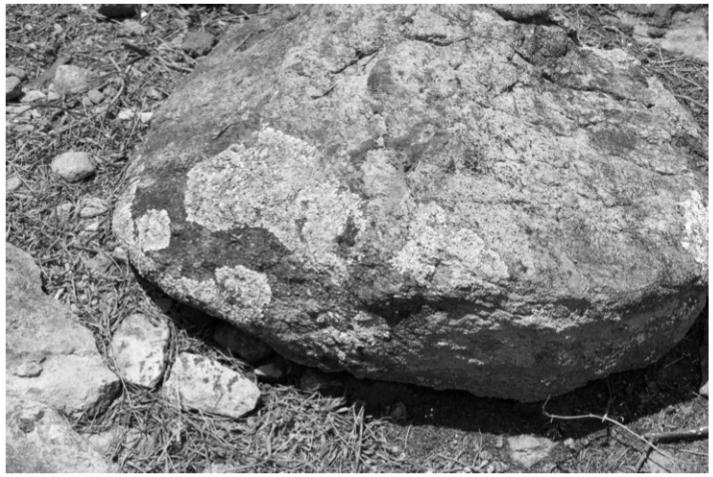
Crustose lichen stage

(Ankur Awadhiya 2015 Dachigam National Park)

Foliose lichen stage

(Ankur Awadhiya 2018 Mukurthi National Park)

Foliose lichen stage



(Ankur Awadhiya 2018 Mukurthi National Park)

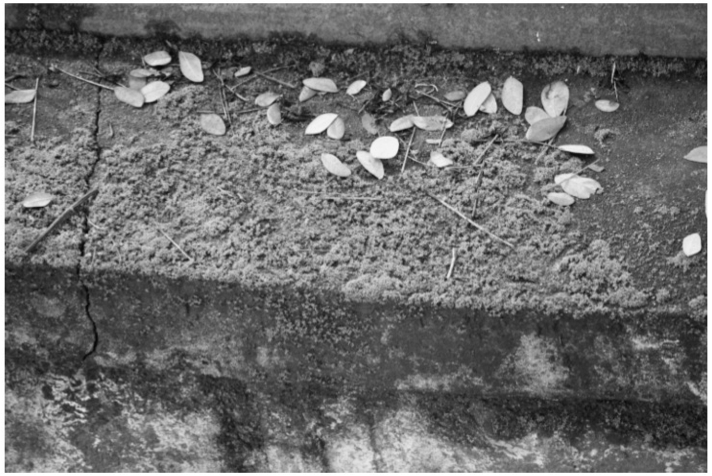
Moss stage

(Ankur Awadhiya 2020 Bhopal)

Moss stage

(Ankur Awadhiya 2020 Bhopal)

Moss stage



(Ankur Awadhiya 2020 Bhopal)

Moss stage

(Ankur Awadhiya 2015 Timli)

Herbaceous stage

(Ankur Awadhiya 2018 Kedarnath Wildlife Sanctuary)

Herbaceous stage

(Ankur Awadhiya 2016 Kaziranga National Park)

Shrub stage

(Ankur Awadhiya 2018 Wild Ass Sanctuary)

Shrub stage

(Ankur Awadhiya 2018 Wild Ass Sanctuary)

Forest stage

(Ankur Awadhiya 2014 Timli)

Forest stage

(Ankur Awadhiya 2015 Manali)

Various stages together

(Ankur Awadhiya 2018 Mukurthi National Park)

Definitions I

1. Ecological succession: "Ecological succession is the process of change in the species structure of an ecological community over time."
2. Sere: "A seral community (or sere) is an intermediate stage found in ecological succession in an ecosystem advancing towards its climax community."
   Kinds of seres:
   a. Hydrosere: A community in water
   b. Xerosere: A community in dry area. Includes
      - Lithosere: A community on rock
      - Psammosere: A community on sand
   c. Halosere: A community in saline body (e.g. a marsh)

Definitions II

3. Pioneer species: "Pioneer species are hardy species which establish themselves in a disrupted ecosystem and trigger the process of ecological succession"
   Characteristics of pioneer species:
   a. ability to grow on bare rocks, nutrient-poor soil or water
   b. ability to tolerate extreme conditions such as heat and cold
   c. less nutritional requirements; often photoautotrophs
   d. small size
   e. short life span with rapid growth; mostly annual species
   f. ability to disperse through spores or seeds; prolific seed production
4. Climax: "A biological community of plants, animals, and fungi which, through the process of ecological succession in the development of vegetation in an area over time, have reached a steady state."
   Kinds of climaxes:

Definitions III

a. Climatic climax: controlled by the climate of the region
b. Edaphic climax: controlled by the soil conditions of the region
c. Catastrophic climax: controlled by some catastrophic event such as wildfire
d. Disclimax: controlled by some disturbance (man or domestic animals)

Characteristics of climax community:

a. vegetation tolerant of environmental conditions
b. high species diversity
c. well-formed spatial structure
d. complex food chains providing stability
e. equilibrium between gross production and respiration, uptake and release of nutrients
f. the species composition continues for a long time
g. the climax community is a good indication of the climate and other conditions of the area

Kinds of succession

1. Primary succession: "Successional dynamics beginning with colonisation of an area that has not been previously occupied by an ecological community, such as newly exposed rock or sand surfaces, lava flows, newly exposed glacial tills, etc., are referred to as primary succession."
2. Secondary succession: "Successional dynamics following severe disturbance or removal of a pre-existing community are called secondary succession."
3. Cyclic succession: "Periodic changes arising from fluctuating species interactions or recurring events."

Lithosere primary succession

Rock → Crustose lichen stage → Foliose lichen stage → Moss stage → Herbaceous stage → Shrub stage → Woodland stage → Climax stage

Hydrosere primary succession

Water → Phytoplankton stage → Submerged stage → Floating stage → Reed swamp stage → Sedge-meadow stage → Woodland stage → Climax stage

Secondary succession

Forest → Forest fire → Forest incompletely destroyed → Herbaceous stage → Shrub stage → Woodland stage → Climax stage

Secondary and cyclic succession are faster than primary succession

Reasons:

1. soil already formed
2. spores and seeds already present in soil
3. regeneration of some plants from roots
4. soil fertility is typically high enough to support organisms

Kinds of succession

1. Autogenic succession: "Brought by changes in the soil caused by the organisms there. These changes include accumulation of organic matter in litter or humic layer, alteration of soil nutrients, or change in the pH of soil due to the plants growing there."
2. Allogenic succession: "Caused by external environmental influences and not by the vegetation. For example, soil changes due to erosion, leaching or the deposition of silt and clays can alter the nutrient content and water relationships in the ecosystems."
   Other examples include volcanic eruptions, meteor or comet strike, flooding, drought, earthquakes and non-anthropogenic climate change.

Phases of succession[3]

1. Nudation: Succession begins with the development of a bare site, called nudation (disturbance).
2. Migration: It refers to arrival of propagules.
3. Ecesis: It involves establishment and initial growth of vegetation.
4. Aggregation: Increase in numbers and population densities.
5. Competition: As vegetation becomes well established, grow, and spread, various species begin to compete for space, light and nutrients.
6. Reaction: During this phase autogenic changes such as the buildup of humus affect the habitat, and one plant community replaces another.
7. Stabilization: A supposedly stable climax community forms.

[3]Clements, F.E., 1916. Plant succession: an analysis of the development of vegetation (No. 242). Carnegie Institution of Washington.

Theories of climax I

1. Monoclimax or Climatic Climax Theory: Advanced by Clements in 1916.
   There is only one climax whose characteristics are determined solely by climate. The processes of succession and modification of environment overcome the effects of other factors such as topography, parent material of the soil, etc.
2. Polyclimax Theory: Advanced by Tansley in 1935.
   The climax vegetation of a region consists of more than one vegetation climaxes controlled by soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity.

Theories of climax II

3. Climax Pattern Theory: Advanced by Whittaker in 1953.
   There is a variety of climaxes governed by responses of species populations to biotic and abiotic conditions. The nature of climax vegetation will change as the environment changes, with the central and most widespread community being the climatic climax.

Thank you

10. Biogeography and geographical distributions

Different areas have different organisms

Differences in climate, together with soil and physiography, generate various natural vegetation and habitats.

Biogeography

The study of the geographical distribution of life on Earth and the reasons for the patterns one observes on different continents, islands and oceans.

What is found where, and why?

An overview of major Indian habitats and their residents

Alpine meadows

(Ankur Awadhiya 2015 Dachigam National Park)

Alpine meadows

(Ankur Awadhiya 2018 Kedarnath Wildlife Sanctuary)

Alpine forests

(Ankur Awadhiya 2016 Dehradun)

Moist deciduous forest

(Ankur Awadhiya 2015 Timli Forest)

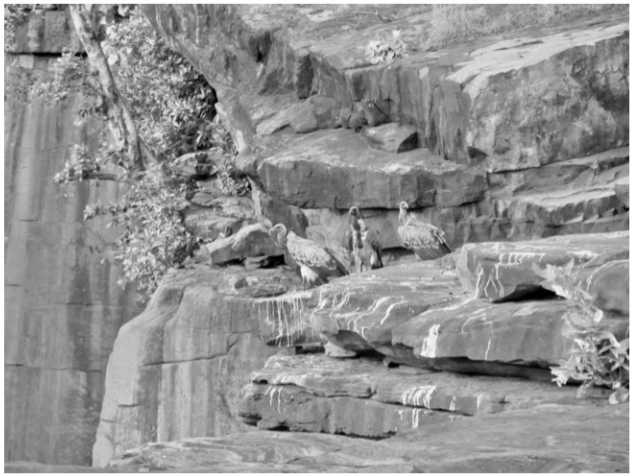
Moist deciduous forest

(Ankur Awadhiya 2018 Mudumalai Tiger Reserve)

Dry deciduous forest

(Ankur Awadhiya 2016 Harda Forest Division)

Dry deciduous forest



(Ankur Awadhiya 2015 Panna Tiger Reserve)

Scrub forest

(Ankur Awadhiya 2015 Ranthambhore National Park)

Sand dunes

(Ankur Awadhiya 2015 Jodhpur)

Spiny tailed lizard in desert

(Ankur Awadhiya 2015 Desert National Park)

Estuary

(Ankur Awadhiya 2015 Jamnagar)

Rann of Kutch

(Ankur Awadhiya 2015 Indian Wild Ass sanctuary)

Flamingos in Little Rann of Kutch

(Ankur Awadhiya 2015 Little Rann of Kutch)

Lagoons: Chilika

(Ankur Awadhiya 2016 Chilika Lagoon)

Brahmaputra floodplains

(Ankur Awadhiya 2016 Kaziranga National Park)

Brahmaputra floodplains

(Ankur Awadhiya 2016 Kaziranga National Park)

Brahmaputra floodplains

(Ankur Awadhiya 2018 Kaziranga National Park)

Shola forests

(Ankur Awadhiya 2015 Coorg)

Equatorial forests

(Ankur Awadhiya 2016 Andamans)

Mangroves

(Ankur Awadhiya 2016 Andamans)

Oceans and seas

(Ankur Awadhiya 2016 Andamans)

Darwin's journal

"Two kinds of geese frequent the Falklands. The upland species (*Anas leucoptera*) is common in pairs, and in small flocks, throughout the island. They do not migrate, but build on the small outlying islets...

The rock-goose, so called from living exclusively on the sea-beach (*Anas antarctica*), is common both here and on the west coast of America, as far north as Chile. In the deep and retired channels of Tierra del Fuego, the snow-white gander, invariably accompanied by his darker consort, and standing close by each other on some distant rocky point, is a common feature in the landscape."

(Voyages of the Adventure and Beagle Vol. III Journal and Remarks, Charles Darwin 1839)

We'll explore the reasons in the next lecture

Thank you

11. Biogeography – Push and pull factors

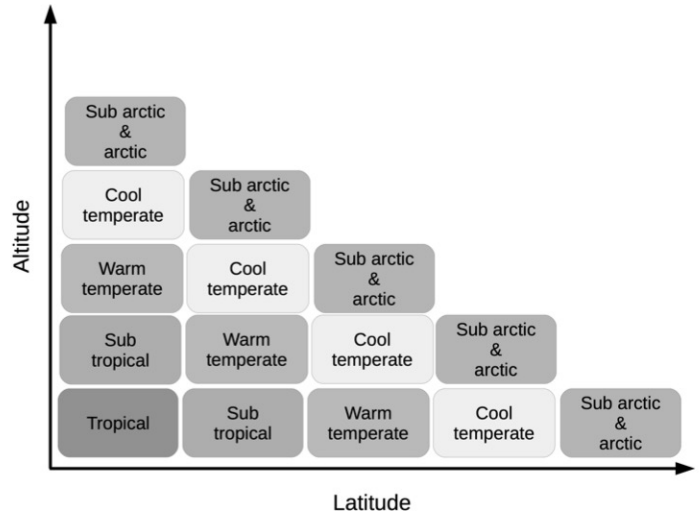
Definitions

1. Biogeography: The study of the geographical distribution of life on Earth and the reasons for the patterns one observes on different continents, islands and oceans.
2. Range: The range or distribution of a species is the geographical area within which that species can be found.

Distribution of species, e.g. polar bears, is limited

Courtesy: Kathy Crane, NOAA Arctic Research Program https://www.pmel.noaa.gov/arctic-zone/gallery_bear.html

Altitudinal zonation: Role of climate



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(Voyages of the Adventure and Beagle Vol. III Journal and Remarks, Charles Darwin 1839)

Why are things where they are?

1. Pull factors: Conditions that attract organisms to an area e.g. food availability, amiable climate
2. Push factors: Conditions that drive organisms from an area e.g. food scarcity, inhospitable climate

Why are things where they are?

(Ankur Awadhiya 2017 Shivalik Range, Uttarakhand)

Several physical and chemical factors simultaneously govern treelines[4]

1. lack of soil
2. drought
3. desiccation of leaves in cold winter
4. lack of snow, exposing plants to winter drying
5. excessive snow, lasting through the summer
6. short growing season
7. rapid heat loss at night
8. excessive soil temperatures in the day
9. mechanical aspect of high winds

[4]Parker, J., 1963. Cold resistance in woody plants. The Botanical Review, 29(2), pp.123-201.

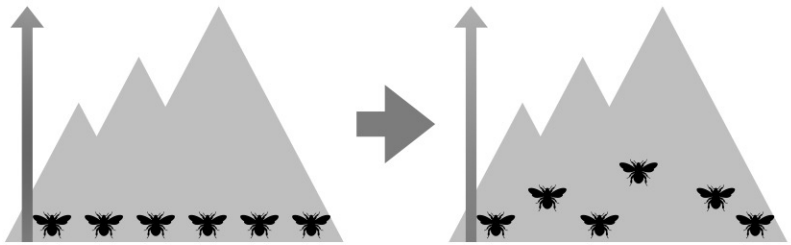
Liebig's law of the minimum

The rate of any biological process is limited by that factor in least amount relative to requirement, so there is a single limiting factor.

Shelford's law of tolerance

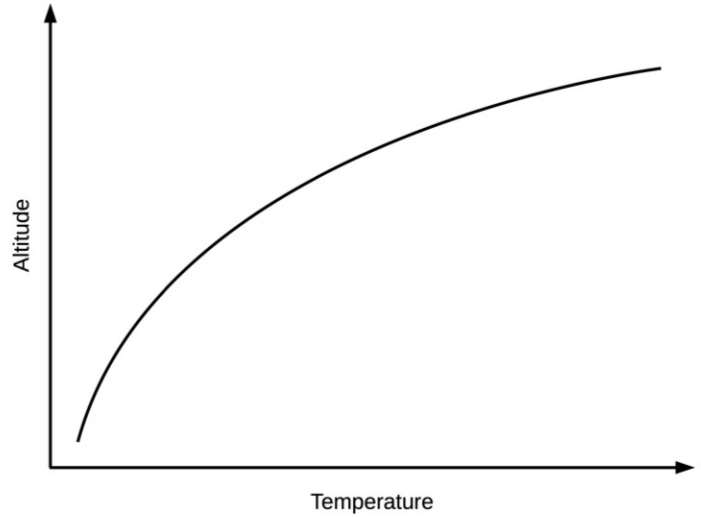
The geographical distribution of a species will be controlled by that environmental factor for which the organism has the narrowest range of tolerance.

Changes in range: Impact of global warming



(Ankur Awadhiya 2018 Indian Forester, 144(10), pp.911-921.)

Median altitude for malaria increases with temperature



Adapted from: Siraj et al. 2014 Science

Biological factors: Allelopathy

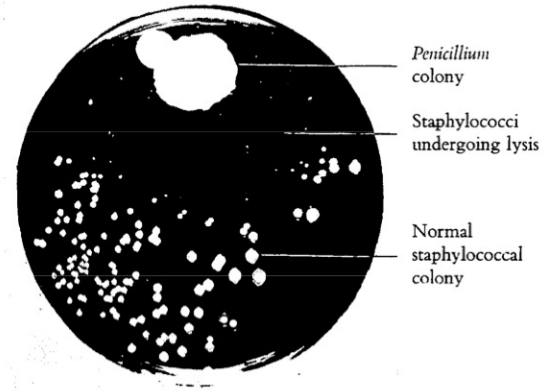


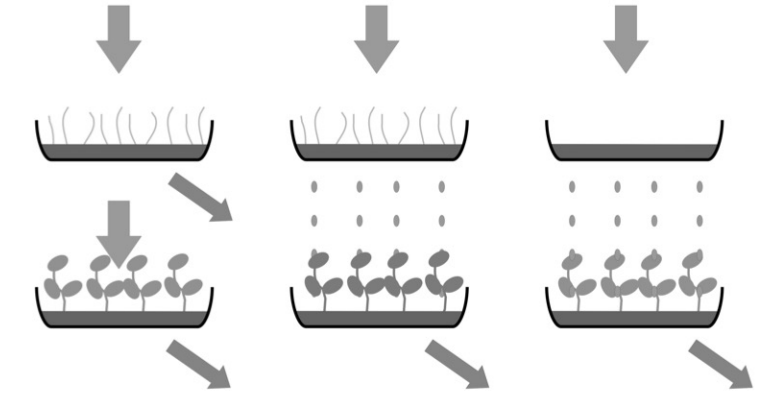
Fig. 1. Photograph of a culture-plate showing the dissolution of staphylococcal colonies in the neighbourhood of a *Penicillium* colony.

(Nobel lecture: Alexander Fleming)

Biological factors: Allelopathy

(Ankur Awadhiya 2016 Harda Forest Division)

Experimental demonstration of allelopathy



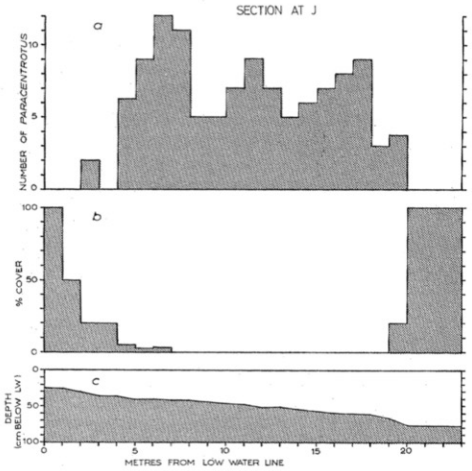
Fresh water $\Longrightarrow$ *Good growth*

Grassroot water $\Longrightarrow$ *Poor growth*

Soil water $\Longrightarrow$ *Good growth*

Adapted from: Krebs, C.J., 1972. The experimental analysis of distribution and abundance. Ecology. New York: Harper and Row.

Predation: Sea urchin (*Paracentrotus*) and algae distribution



(Kitching, J.A. and Ebling, F.J., 1961. The ecology of Lough Ine. The Journal of Animal Ecology, pp.373-383.)

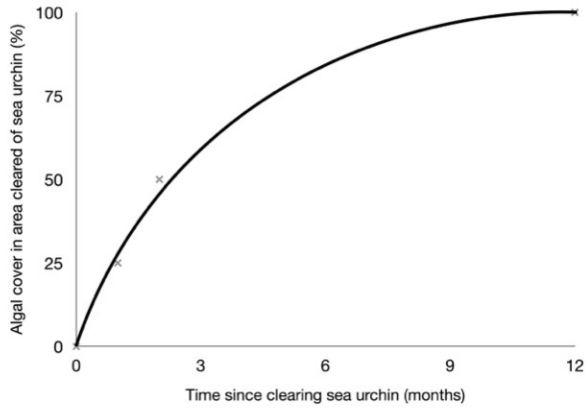
Predation: Sea urchin (*Paracentrotus*) and algae distribution

$$More\ sea\ urchin \implies Less\ algae$$

$$Less\ sea\ urchin \implies More\ algae$$

(Kitching, J.A. and Ebling, F.J., 1961. The ecology of Lough Ine. The Journal of Animal Ecology, pp.373-383.)

Removal of sea urchin leads to recolonisation by algae



(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Predator governs distribution and abundance of prey

Four criteria need to be fulfilled[5]:

1. "the organism does not survive when transplanted to a site where it does not normally occur, unless it is protected from predators by cages.
2. there is an inverse correlation between the distribution of the organisms and the suspected predator, or alternatively, in the places where it occurs the organism is inaccessible to the predator.
3. the suspected predator is able to inflict lethal damage on the prey in experiments in cages, or can be observed to do so in the laboratory.
4. there is direct evidence that the suspected predator is responsible for destruction of the prey in transplantation experiments."

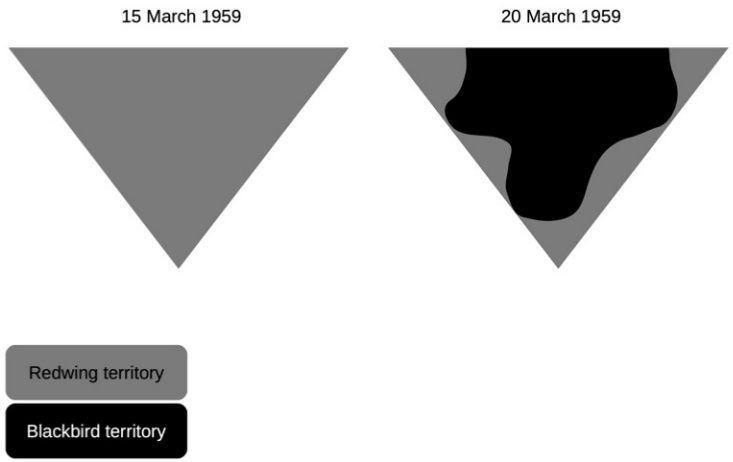
[5]Kitching, J.A. and Ebling, F.J., 1967. Ecological studies at Lough Ine. In Advances in Ecological Research (Vol. 4, pp. 197–291). Academic Press.

Prey governs distribution and abundance of predator[6]

1. *Drosophila pachea* breeds in the stems of senita cactus.
2. When reared in laboratory media, cactus is needed as a dietary supplement.
3. In the absence of the cactus, the larvae die.
4. $\Delta^7 - Stigmasten - 3\beta - ol$, a sterol found in the cactus can replace the cubes of cactus in the laboratory medium.
5. Thus, the cactus governs the distribution of the drosophila through the means of the sterol.

[6]Heed, W.B. and Kircher, H.W., 1965. Unique sterol in the ecology and nutrition of Drosophila pachea. Science, 149(3685), pp.758-761.

Interspecific competition governing distribution[7]



Adapted from: Orians, G.H. and Collier, G., 1963. Competition and blackbird social systems. Evolution, 17(4), pp.449-459.

Population control by inhibition: The peach replant problem[8]

Particulars	Fruit yield (lb. per tree)
Peach following peach	92.6
Peach following apple	212.5

[8]Proebsting, E.L., 1950. A case history of a "peach replant" situation. In Proceedings. American Society for Horticultural Science (Vol. 56, pp. 46-8).

Behavioural factors: Habitat selection

"Habitat selection refers to a hierarchical process of behavioural responses that may result in the disproportionate use of habitats to influence survival and fitness of individuals[9]."

[9]Jones, J., 2001. Habitat selection studies in avian ecology: a critical review. The auk, 118(2), pp.557-562.

Habitat selection has both innate and learnt components[10]

Chipping sparrow	% Time spent in pine	% Time spent in oak
Wild-caught adults	71	29
Laboratory-reared, no foliage exposure	67	33
Laboratory-reared, oak foliage exposure only	46	54

[10]Klopfer, P., 1963. Behavioral aspects of habitat selection: the role of early experience. The Wilson Bulletin, pp.15-22.

Other factors

1. Migration: Regular, seasonal movement of animals, often along fixed routes.

Purpose:

a. Better resources (e.g. food, breeding sites)
b. Shift from harsh to amiable climate

Demoiselle cranes

(Ankur Awadhiya 2015 Jodhpur)

Demoiselle cranes

(Ankur Awadhiya 2015 Jodhpur)

Other factors

1. Migration: Regular, seasonal movement of animals, often along fixed routes.
2. Dispersal: The movement of individuals away from their place of birth or hatching or seed production into a new habitat or area to survive and reproduce.

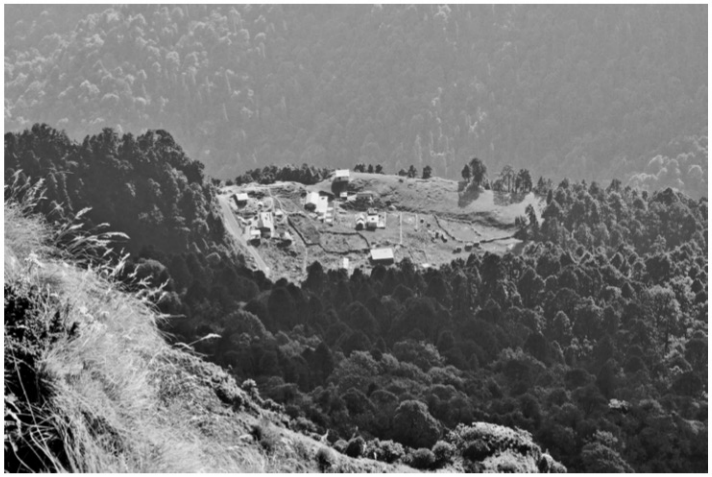
Three modes of dispersal

a. Diffusion: Gradual movement over several generations, often across hospitable terrain
   e.g. movement of lions across the Gir landscape
b. Jump dispersal: Quick movement over large distances, often across unsuitable terrain
   e.g. dispersal of zebra mussel through ballast water
c. Secular dispersal: Diffusion in evolutionary time; migrants are divergent from original population
   e.g. dispersal of humans out of Africa

Other factors

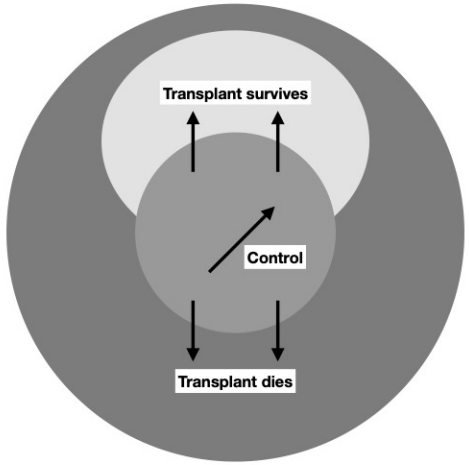
1. Migration: Regular, seasonal movement of animals, often along fixed routes.
2. Dispersal: The movement of individuals away from their place of birth or hatching or seed production into a new habitat or area to survive and reproduce.
3. Anthropogenic factors: The man-made factors.
   e.g. clearing of forests, pollution

The human factor: Clearing of forest



(Ankur Awadhiya 2017 Shivalik Range, Uttarakhand)

Identifying the potential range: Transplant experiments



(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Outcomes and interpretations of transplant experiments

A. Transplant successful $\Longrightarrow$ distribution is limited either because:

1. the area is inaccessible (physical barrier), or
2. time has been too short to reach the area (dispersal time insufficient), or
3. the species fails to recognise the area as a suitable living space (habitat preference).

B. Transplant unsuccessful $\Longrightarrow$ distribution is limited either because:

1. other species (predation, parasitism, competition, etc.), or
2. physical and chemical factors.

Analysis of causal factors of distribution

DICHOTOMOUS KEY

(1) Is species absent because area is inaccessible: YES → DISPERSAL
(1) Is species absent because area is inaccessible: NO
If NO then
(2) Is the habitat an unpreferred habitat for the species: YES → HABITAT SELECTION
(2) Is the habitat an unpreferred habitat for the species: NO
If NO then
(3) Are other species causing predation, parasitism, competition or diseases: YES → INTER-SPECIFIC INTERACTIONS
(3) Are other species causing predation, parasitism, competition or diseases: NO
If NO then
(4) Species absent because of physical or chemical factors

(b) A dichotomous key to understand the absence of species from a location.

(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Thank you

12. Human Ecology – Introduction and impacts in anthropocene

We live in the anthropocene

"A proposed epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems, including, but not limited to, anthropogenic climate change."

Human Ecology

The study of the relationship between humans and their environment.

The environment can be:

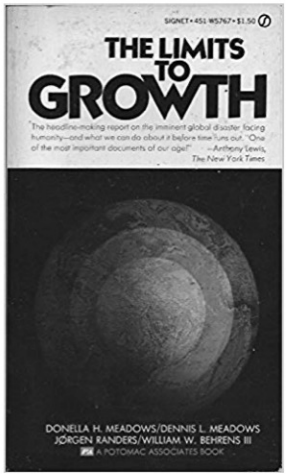
1. natural
2. social
3. built environment

The naturalisation of humans and the humanisation of nature

3 concepts about the nature of relationship between humans and their environment:

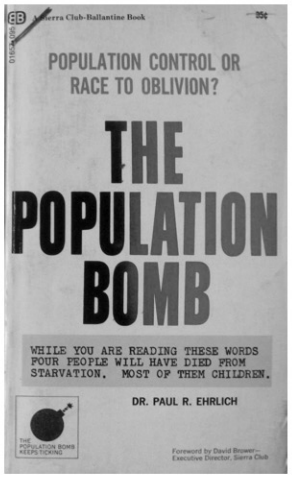
1. environmental determinism: humans adapted to, and dictated by natural forces; more common in primitive societies
2. possibilism: the phenomenon of humans changing the environment, and thus 'humanising' nature which begins to have the imprints of human endeavour
3. neodeterminism (aka stop and go determinism): possibilities are created within the limits set by nature

Limits to growth



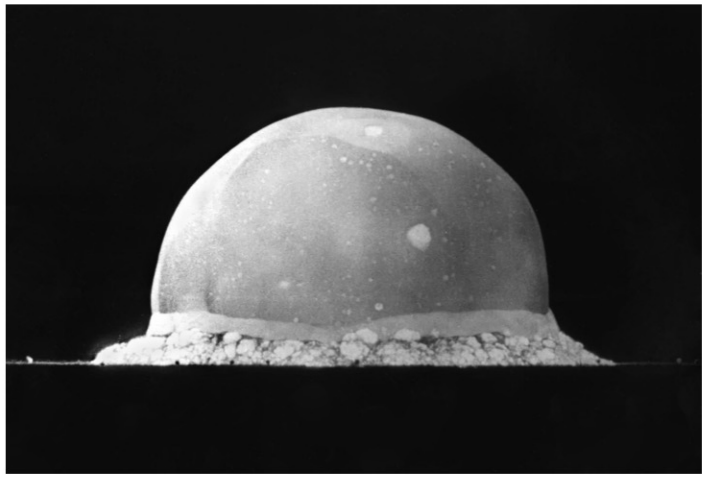
(https://www.amazon.in/Limits-Growth-Donella-H-Meadows/dp/0451057678)

Population Bomb



(https://www.amazon.com/Population-Bomb-Paul-R-Ehrlich/dp/0345216571)

Trinity 1945: The beginning of Anthropocene



(By Berlyn Brixner / Los Alamos National Laboratory Wikimedia curid=4179325)

Anthropocene

"A proposed epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems, including, but not limited to, anthropogenic climate change."

Quantum of human impacts

$$I = P \times A \times T$$

where

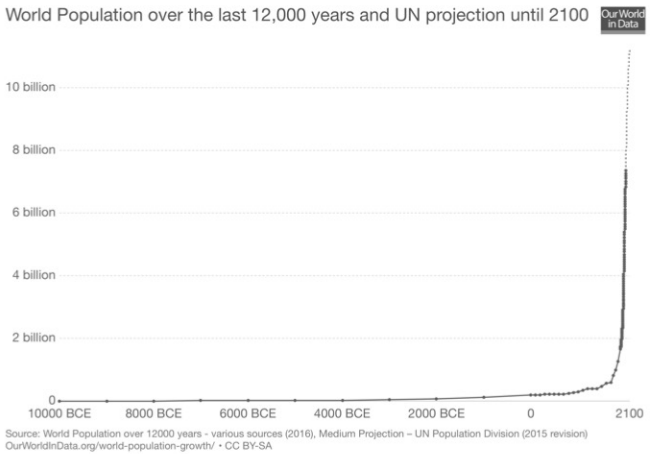
I = impact of human activity on the environment

P = Population in an area. The area could be as large as the whole world.

A = Affluence (average consumption of each person in the population). Affluence is generally measured through the values of GDP per capita.

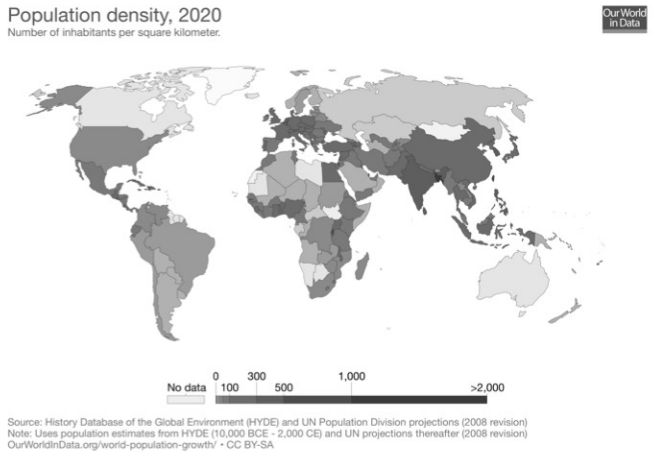
T = Technological advancement, a measure of how resource intensive the production of affluence is.

World Population



(https://ourworldindata.org)

Density of population



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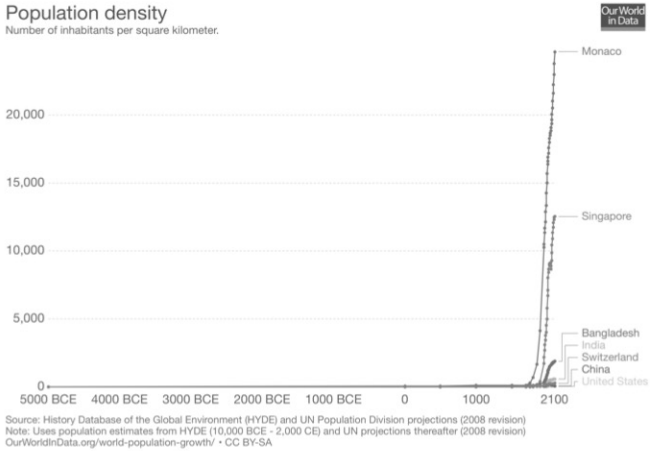
Population densities in countries

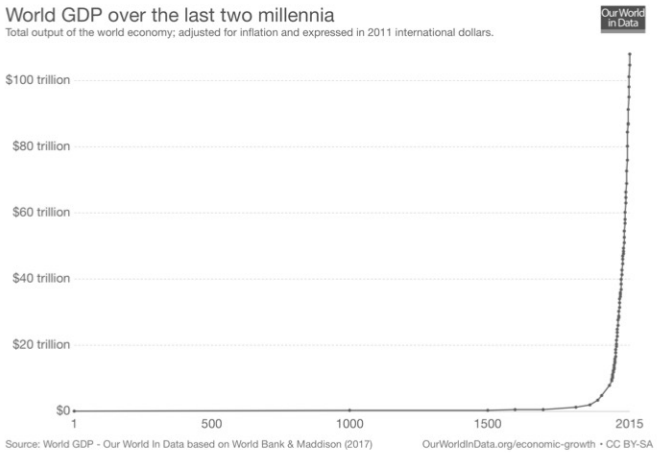


(https://ourworldindata.org)

Changes in Industrial Output with time

(https://ourworldindata.org)

Changes in World GDP with time



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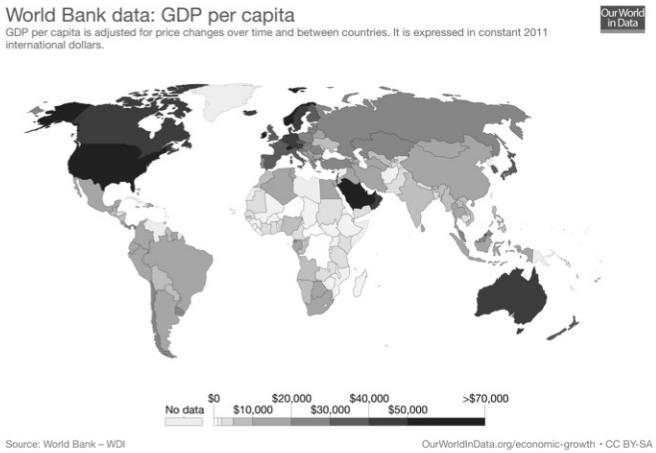
GDP per capita



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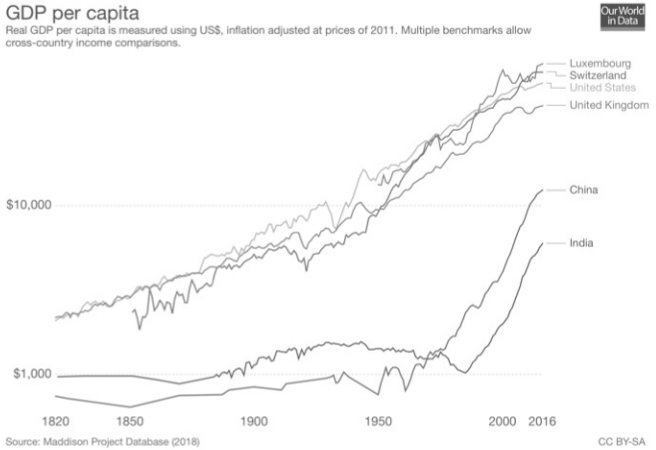
Changes in GDP per capita with time

(https://ourworldindata.org)

Changes in GDP per capita with time



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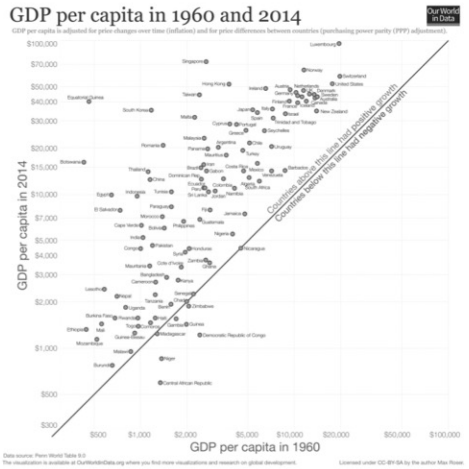
Increase in GDP per capita with time



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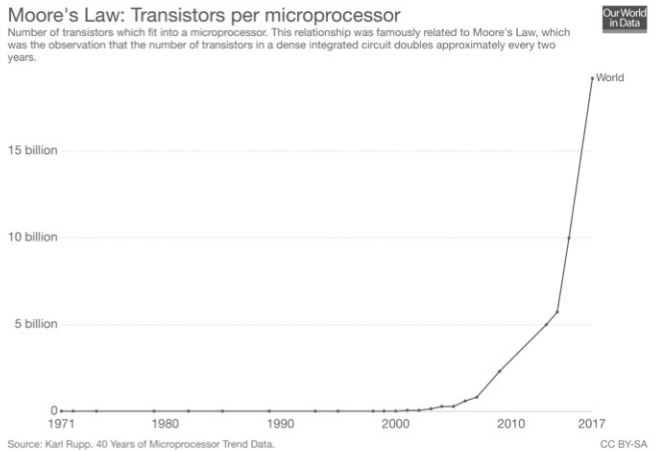
Technological progress: Moore's law



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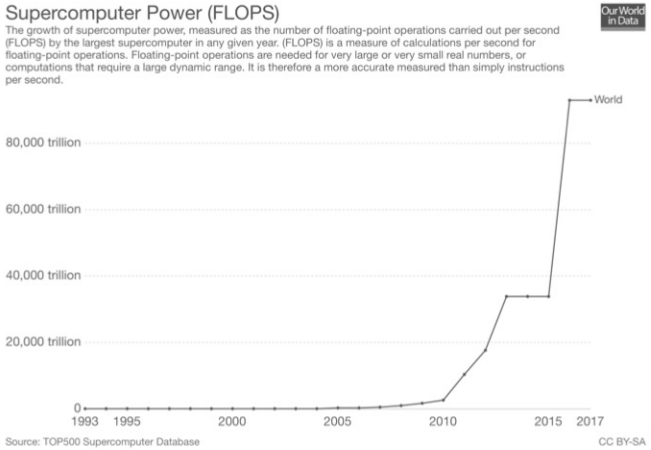
Technological progress: Supercomputer power



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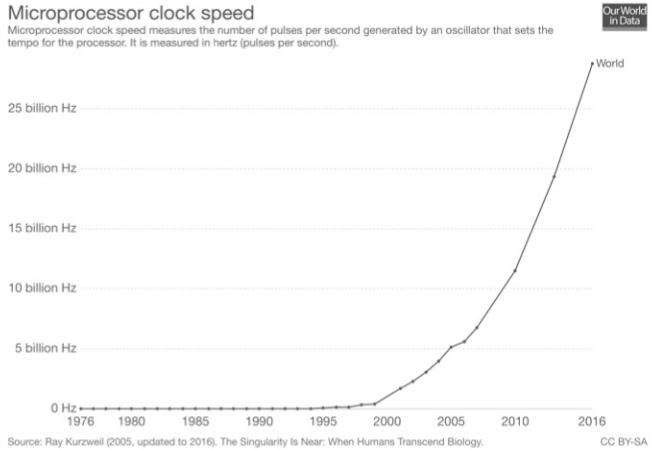
Technological progress: Microprocessor speed



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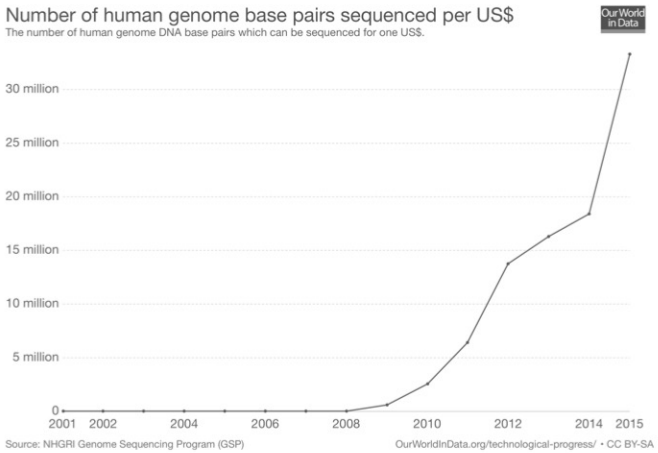
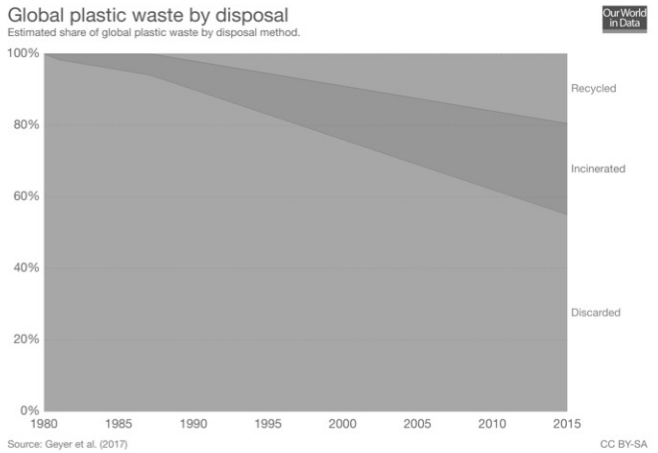
Technological progress: Sequencing cost



(https://ourworldindata.org)

Technological progress: Plastic recycling



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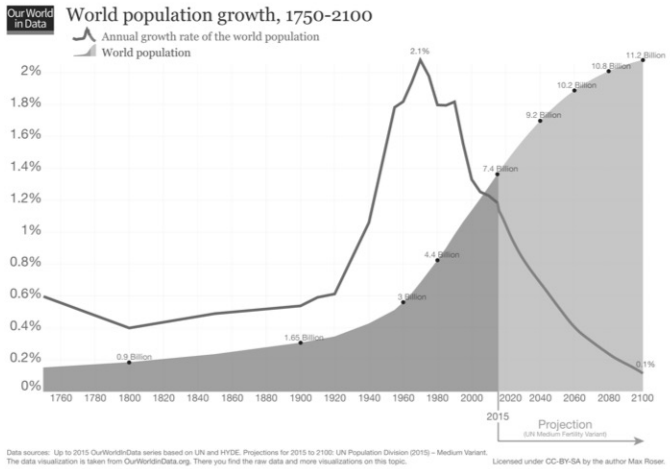
Human impacts on the environment I

1. Overconsumption
2. Habitat destruction
3. Desertification
4. Ocean acidification
5. Ozone depletion
6. Changes in biogeochemical cycles such as nitrogen cycle
7. Loss of biodiversity and extinctions
8. Changes in distribution of organisms, changes in biodiversity
9. Climate change
10. Soil erosion and changes in geomorphology: deposits derived from concrete, lime, mortar or other calcareous material outside the cave environment
11. Changes in stratigraphy due to increased sediment load and deposition (reasons: deforestation, construction activities, etc.)

Human impacts on the environment II

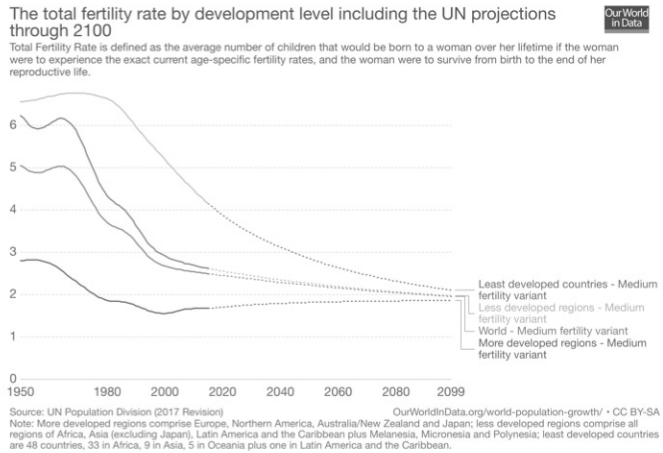
12. Changes in elements in the atmosphere: C-12 released from fossil fuels, radionuclides released from nuclear fallout and atomic reactors
13. Changes in soil: water logging, desertification, build-up of pesticides and other chemicals
14. Introductions and invasive species
15. Pollution, including light pollution
16. Coral bleaching
17. Wars

The silver lining: We've crossed peak growth rates



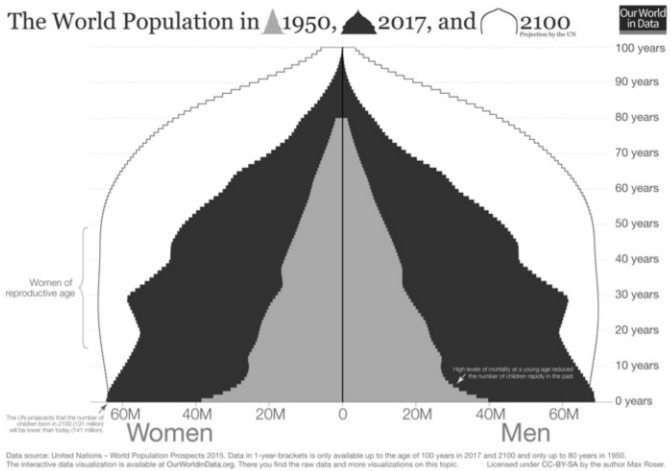
(https://ourworldindata.org)

The silver lining: Reducing fertility rates



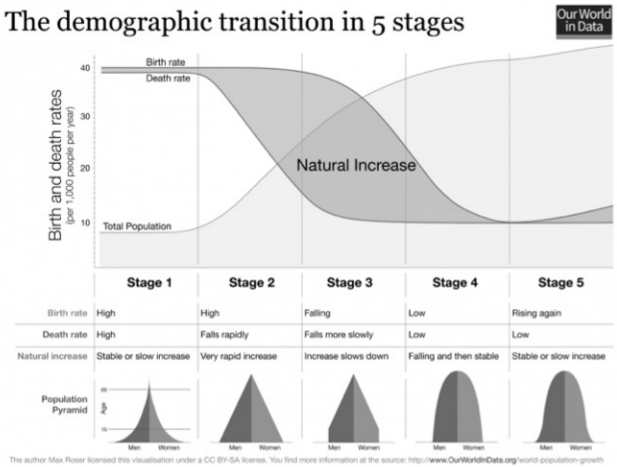
(https://ourworldindata.org)

The silver lining: Reducing growth rates



(https://ourworldindata.org)

The silver lining: Demographic transition



(https://ourworldindata.org)

Thank you