Conservation Biology Final Summary

This review encompasses every lecture from BIOL3130 in the Winter 2013 semester. Every note and relevant diagram from the lecture slides is included, as well as notes taken by myself and three other students. The homework questions for the course are included at the bottom of the document.

For questions or comments, email allanah@uoguelph.ca

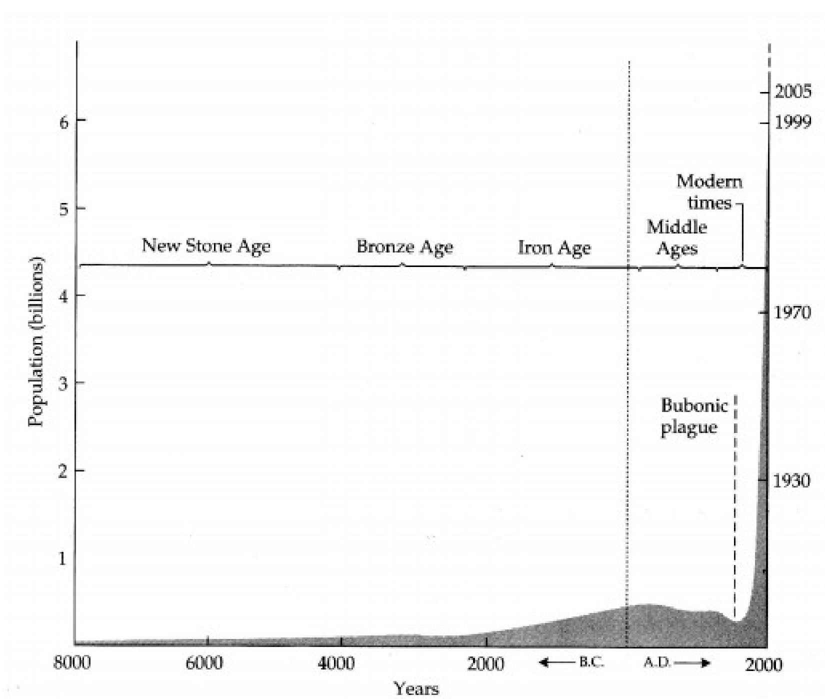
Lecture 1 - Introduction to Conservation Biology

Introduction to the arrangements and methods of the class; assignments and midterms reviewed.

Lecture 2 - History of Conservation Biology

Planet Earth - Home to Humans

- Humans are the dominant species on Earth
- They are a health issue to the planet
- They have a very different impact from 10,000 or even 100 years ago
- Dramatic increase in population (and therefore impact) since the industrial revolution - this is partly due to the advent and increase in availability in medicine



- As a result of our presence, every ecosystem has been altered - stress on ecological supports and resources
- 98% of grasslands have been converted for agricultural use, urbanity, or taken over by pollution
  - Many extinctions

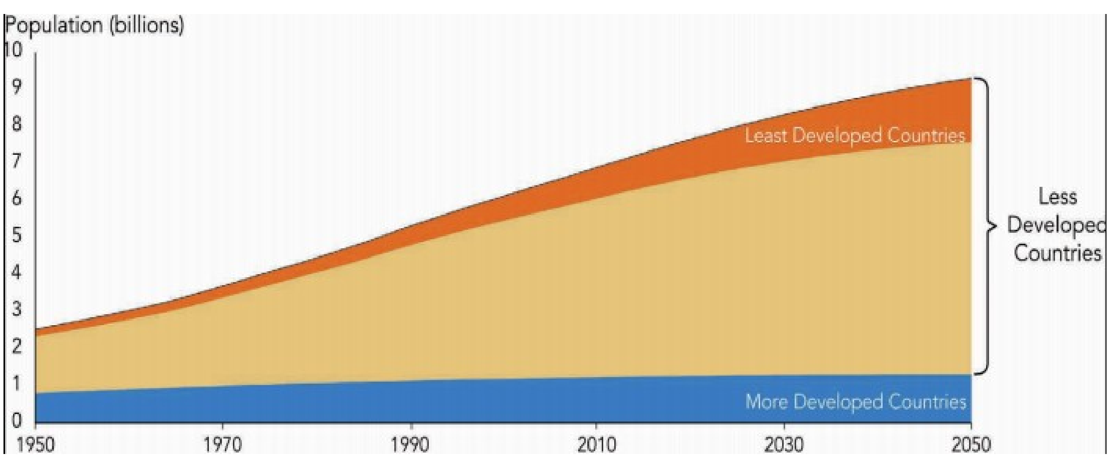
- Genetic diversity crashed
- Topsoil displaced
- Climate change
- Chemical disruptions

Some Historical Context

- Humans “may” have been responsible for mega-fauna extinctions in the Americas shortly after human colonization from Asia 11,000 years ago
    - No extreme enough climate change to explain away the massive extinctions, even with less than 100 million humans at the time
    - Humans are very inefficient with their food resources
        - Native Americans ran the bison off cliff en mass
        - Europeans stampeded horses off cliffs
            - Bones of >10,000 horses were found at the base of a cliff in France
- Aristotle (382-334 BC) commented on the widespread destruction of forests in the Baltic region
- Barren landscapes of Turkey, Syria, Iraq, and Iran are unnatural deserts that resulted from massive exploitation of fragile woodlands
- India, Bangladesh, and Pakistan – major changes over the past 2000+ years
- Deforestation of Europe in the early 18th century, forest areas maintained as private game management and royal preserves
- In Great Britain, many of the native forests were gone by the 12th century
- Southeastern Ontario has been largely deforested during the past 150 years
- Our impact has been large, and largely negative

The Good News?

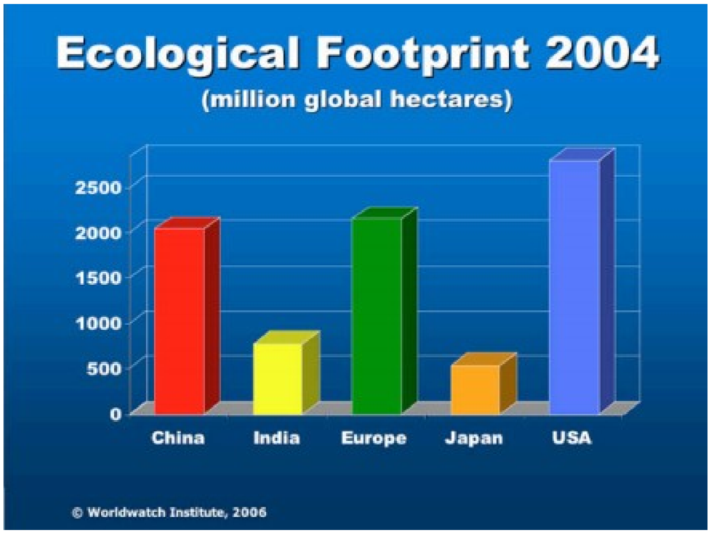
- Exponential increase in human populations is going down!



- Less developed countries – birthrates are high
  - Family survival is based on unskilled, uneducated labour pool – field work
  - More kids = richer, more workers – economic incentive
- Developed countries – experiencing a **Demographic Transition.**
  - Low mortality (medical care)
  - Decreased fertility (less economic incentive to have large families)
- As less developed countries become more developed, there will be a global demographic transition.
- Human populations estimated to stabilize at 10 billion people in 2100

The Bad News

- **Ecological Footprint** – the amount of land and water resources consumed to support lifestyle, grow food, and assimilate wastes.



- It's not just the number of people which has a negative effect – how we use our resources is important. Currently, ours are HUGE.
- 1970s – consumption patterns exceeded the earth's annual carrying capacity.
- 83% of the earth's land surface shows evidence of our impacts
  - Agriculture
  - Urbanity, suburban sprawls, roads
  - Pollution
  - 98% of fertile grasslands have been converted to agriculture

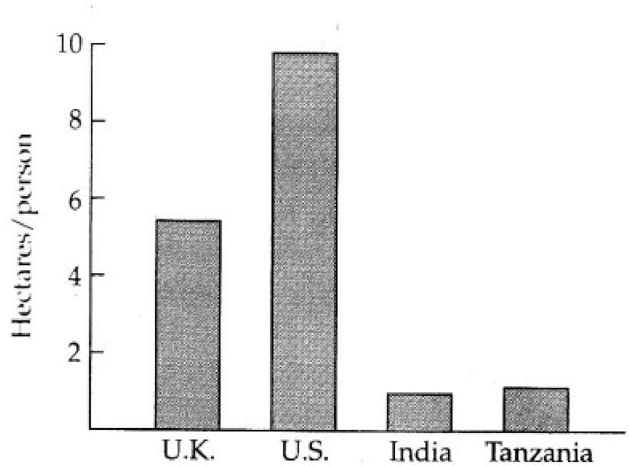
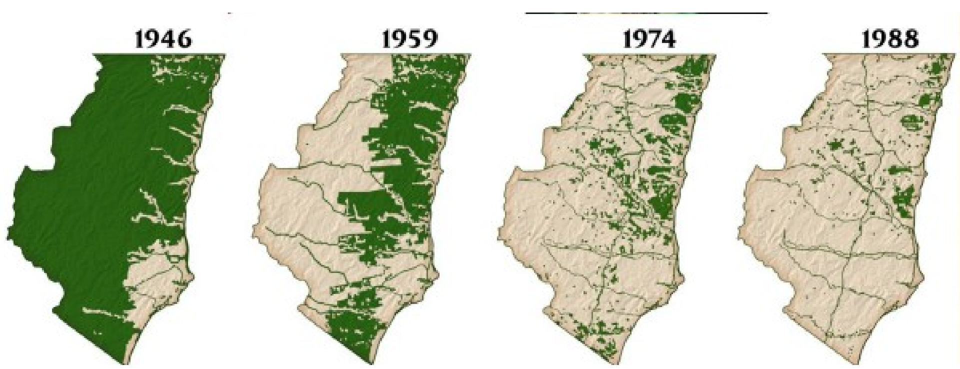


Figure 1.3 Number of global hectares per person needed to support current lifestyles in the U.K., U.S., India, and Tanzania. (Modified from World Wildlife Fund 2003.)

- The above bar chart – Per person/capita
    - With an increase of development, population slows but per person use of resources increases
- >4 earths are currently needed to support the level of consumption used by North Americans.
    - US = 10x higher than India/Tanzania
- Loss of resources in natural environmental systems are driven by underdeveloped countries wanting to become developed, and attain the luxuries and lifestyles of developed countries
- Many European countries are working to lower their ecological footprints



- The above picture: Forest cover in Brazil
- With our consumption of natural resources, the environment becomes increasingly fragmented and stressed, and unable to support great biodiversity/indigenous life.

More Long-term Changes

- Hawaiian Islands
    - Half of Hawaii's native birds went extinct soon after the Polynesians arrived
    - Half of the remaining species of birds went extinct after Captain James Cook arrived

    - This is typical of human impact
- These are the reasons for the establishment of protected areas

Today

- We consume 20-40% of the planet's annual **Net Primary Productivity (NPP)**
    - NPP – Plant production through photosynthesis
    - Production of primary producers – they convert the sun's energy into biomass through photosynthesis
        - Phytoplankton
    - 35% of the NPP from oceanic shelves
- We also consume 60% of freshwater runoff (irrigation, drinking water)
    - Demands on freshwater will increase as environmental degradation increases
- Consumption is highly unequal
    - The US has 4% of the global population but consumes 30% of the oil produced

Optimism

- Population growth rates are declining in many regions; growth rates are negative in some countries
- Humans as "rational" beings – we have the potential to change our consumption patterns
    - Challenges: inertia and fear
        - Inertia – people are unwilling to give their luxuries up
        - Fear – people are scared that the economy will tank if consumption is reduced.
            - "The economy will tank if we reduce consumption!"
            - "Our natural resource industries will tank if we set constraints on harvest!"
    - Overcoming the challenges
        - Sustainable development, alternative fuels, alternative thinking, crisis management etc.
        - Conservation biology!
        - Money is the driving force behind human consumption – convincing people through their pocketbooks is the way to go!

Conservation Biology

- Response by the scientific community to the environmental crisis: pollution, loss of biodiversity, loss of ecosystem services
- The latest phase of a long-standing interest in preserving our natural resources

- We have the potential to change our consumption patterns
- Conservation biology provides the science to help these initiatives

A Brief History of Conservation in North America

- Europe has very few "pristine" places left – saw North America as pristine
  - Native Americans had made a significant impact already
- Exploited products for themselves and the European market (beaver, wood, turpentine, gum)
- Lots of pressure on local ecosystems
- Lots of land was used for agriculture

The New World

- Early settlers had no interest in conservation
- Driven by fear, religion, by desperation (escaping persecution in Europe)
  - Europeans brought religious and superstitious beliefs
    - Puritans – Devil lives in the forest
    - Fairy tales – Hansel and Gretel, Little Red Riding Hood
  - Woods were to be exploited or feared (monsters)

Then

- As cities grew, so did interest in conservation
  - A larger population of people not directly dependant on the forest
    - Saw more value in keeping the forest around
- Reaction against the "de-humanizing" effects of the industrial revolution and urban living
- Shifts in thinking (God could only be found in untrammeled nature, and the peoples that lived there ("noble savages") - Jean-Jaques Rousseau).
- Ecotourism!

Transcendentalism

- The first of three schools of thought that emerged at this time
  - Pushed the idea in North America that wilderness nearby is important; destruction of wilderness separates you from the divine – opposite to the puritan view (God is in the forest, not the Devil)
- **The spiritual quality of life**
  - Spiritual and emotional wellness - "romantic" view of untouched nature.
- Focused on the **preservation** of **pristine areas**

- Henry Thoreau, Ralph Waldo Emerson, John Muir
  - Muir – one of the first to argue for a national movement to preserve nature
    - Seierra club (non-profit in environmental policy)
- "The beauty and perfection of nature reflected some higher spiritual truth."
- Turned early puritanical views on their heads – development bad, nature good
- Massive resurgence of interest in the 1960s and 1970s.
- Art during this time featured beautiful landscapes, no humans

Resource Conservation Ethic

- Conservation must include development, but is sustainable
- **Conservation** of **resources**
- Gifford Pinchot – first head of the US Forest Services
  - Resources are to be <u>used.</u>
  - Things in nature are either useful, useless, or noxious.
    - Not useful = not worth keeping
  - Natural resources feed the economic machine
  - Natural resources contribute to the **material quality of life.**
  - Nature should be protected, yet open for all forms of use (**multi-use philosophy**)
    - Recreation, hunting, trapping, fishing, logging, etc - all sustainably
    - Model of Canadian and American environmental protocols
- **First Principle** : Meet current needs without compromising the needs of future generations (**sustainable development)**
- **Second Principle**: Use resources efficiently – no waste (eg. Parks).
- Schism still exists between Transcendentalism and Resource Conservation Ethics

The First Calls for Preservation

- The first parks
  - George Catlin (1830) – first to suggest a government-created park
  - Yellowstone (1872) – conservation programs are initiated
  - Banff National Park (1883)
  - Adirondack Hills (1885)
  - US Forest Service created a vast network of national forests and grasslands (1905) – 193 million acres.

- Motives:
  - Prevent rampant development (ex. Niagara Falls)
    - 1970s - “Free Niagara” movement
    - US - “Niagara preservation” initiated
    - Canada - “Queen Victoria National Park” created
  - Protect drinking water
  - The weird and unusual (geysers)
  - A place for “health and refreshment”
- Before this, there was no national vision for preservation, no valuing wilderness for its own sake
- The creation of parks coincides with the destruction of the idea of the frontiersman – no untarnished environment left. Nothing left to “conquer” in the late 1800s. Teddy Roosevelt-types were gone.
- A period of incredible transformation – North Americans had come to define themselves as different from the Old World; tougher, hewn by the challenges of the pioneer life.
- Conflict arose for preservation as things became scarce vs. development as things became scarce
  - Do we take land as a park, or do we develop it for human use?

Evolutionary-Ecological Land Ethic

- Aldo Leopold
  - Found the Resource-use model inadequate.
  - Development of ecology and evolution sciences indicated nature was not simply a collection of independent parts
  - “Thinking like a mountain”
  - Everything is connected – interference can have extremely negative effects
    - The watch analogy
      - We see the components of a watch – minute, second, hour hands; all useful, all visible, easily seen
      - We do not see the many, many other components – invisible, but work together to make the clock run.
      - If the invisible aspects are gone, the clock does not run
      - INTERCONNECTIVENESS
  - Pushed for scientific principles to guide land management
    - Ecology and evolutionary biology

- **Nature is a complicated and integrated system**
- **Humans are a part of nature**
    - Must be taken into account when developing conservation strategies

20th Century to Today

- Resource Conservation Ethic
    - Dominant paradigm followed by public resource agencies
    - Does contain sustainable development, thinks about future generations
- Romantic-Transcendental Conservation Ethic (without religion)
    - Basis for activism by many private conservation organizations (such as Greenpeace)
- Evolutionary-Ecological Land Ethic
    - Most biologically sensible and comprehensive of the three, allows for predictions of our effects on the natural world
    - How aspects in nature are going to respond to human interference – takes into account the ecological, economical, and spiritual needs of the humans in the area

Timeline

•Power of the Federal Government in conservation increases: national policies
•Restrictive regulations on hunting, fishing, and resource extraction (e.g., bags limits)
•1916 Migratory Bird Treaty with US
•1930 Canada Parks Act
•1964 Wilderness bill in the US (9/190 million acres converted to "wilderness")
•1960s/1970s: growing concerns about our future
Silent Spring [Rachel Carson], The Population Bomb [Paul Ehrlich], Future Shock [Alvin Toeffler])
•1970 -The first Earth Day
•1973 US Endangered Species Act (ESA)
•1978 Soule organizes the first CB conference (1985 – SCB)
•1992 Earth Summit (Rio) Biological diversity
•1997 – Kyoto Protocol (greenhouse gases)
•2002 – Species at Risk Act (SARA – Canada)
•2009 – Copenhagen Conference...

- ESA – strongest piece of environmental legislation in the world
- SCB – Society for Conservation Biology
- Migratory animals are a challenge
    - Countries must co-operate with conservation activities

- Harder with animals which travel between borders/between developed and undeveloped countries
- Animals may be protected on one end, but not on the other
  - Less developed countries may not be stable/have the resources enough to adequately protect a species, or may have different cultural views on the conservation of that species

ESA vs SARA

- Conservation acts are only as good as their wording

> **ESA**
> SEC. 4. ø16 U.S.C. 1533¿ (a) GENERAL.—(1) The Secretary shall by regulation promulgated in accordance with subsection (b) determine whether any species is an endangered species or a threatened species because of any of the following factors:...
>
> **SARA**
> The Governor in Council may, on the recommendation of the Minister, by order amend the List in accordance with subsections (1.1) and (1.2) by adding a wildlife species, by reclassifying a listed wildlife species or by removing a listed wildlife species, and the Minister may, by order, amend the List in a similar fashion in accordance with subsection (3).

- ESA is much stronger than SARA, because of the wording in the document.
  - Enforcement
    - "Shall" - must/will
    - "May" - Government discretion – depends on the judge; whether they rule in the spirit or word of the law

Many Old Conflicts Remain

- Preservation vs Conservation
  - The Alaska Wilderness Refuge – the US needs more domestically produced oil, but this puts pressure on the wilderness refuge
- Wilderness: Good vs Bad
- Moderate vs Extreme conservation movements
  - Greenpeace
- Science vs Advocacy
  - Should scientists be involved in creation of policy? YES

- International Conservation
  - Just beginning in some areas
    - Canada is stable economically and socially, and still manages to fuck up species
    - Unstable countries may not have the resources to put into protection
  - The risks of colonialism
    - Who are we to tell other countries what to do?

What is Conservation Biology?

- Conservation Biology is the scientific study of the nature and status of earth's **biological diversity** with the aim of **protecting** species, habitats, and ecosystems from excessive **extinction** rates that are linked to the modern human enterprise (Wikipedia).
- "The science of scarcity and diversity." M. Soule (1986)
- "The applied science of maintaining the Earth's biological diversity" or more simply, "Biology as applied to conservation issues." M. Hunter (1996, 2002)
- "Conservation Biology should be considered a crisis discipline." R. Primack (2006)
- It is a multidisciplinary discipline including multiple fields, based on the natural sciences
- Crisis Management
  - Unites theoretical perspectives (often slow to develop) with the need for rapid responses to environmental change
    - Scientists don't like to make fast decisions
    - Climate change: we are currently progressing along the worst case scenario (scientists spouting this claim in earlier decades were dismissed as alarmists)
  - Precautionary Principle
    - Because we never have enough data
    - Avoid practices that could lead to hard or degradation
    - Burden of proof on the people who want to make changes
      - Must prove that no negative effect will occur

<u>Lecture 3 - Conservation Genetics</u>

Conservation Biology

- Conservation Biology is different from other disciplines – it is inexact
  - Inexact because of the complexity of genes, populations, communities, ecosystems, and their interactions
    - Defining things and their interactions

    - Use of the precautionary principle for crisis management – up to the developer to prove no harm will occur)
    - Our concerns often outweigh our solutions
- Value-laden discipline
    - Theoretically, science is objective
    - Mission-oriented - to prevent loss of biodiversity
    - Public tends to be more concerned about charismatic megafauna
    - There are different definitions of wilderness
        - How to appeal to different people to funding for conservation?

Guiding Principles of Biodiversity

- Evolution
- The ecological world is dynamic and generally non-equilibrium
- Humans must be included in conservation planning

Evolution

- Variation exists in populations and some is heritable.
    - Variation may change fitness
- Populations produce more offspring than the environment can support.
- Individuals with traits allowing them to survive and produce reproducing offspring are the most fit.
- Over time, populations adapt to changing conditions

Dynamic Ecology

- Current populations are not necessarily stable
    - Do we protect sources (populations diversifying in a good habitat) or sinks (populations losing numbers)
        - Sinks may become a source with an environmental change
    - Few ecosystems are free from disturbance – some even require disturbance to persist
        - Fire cycles – some evergreen trees
    - Stability is dependant n time scale
    - Novel ecosystems may need novel approaches

Human Presence

- Few landscapes have developed without human impact
- We must consider local knowledge, traditional environmental knowledge, and the knowledge of woodlot owners – this is a good place to start research
- Conservation initiatives must be user-friendly; people must want to do them
    - Will it save them money? Will it have no cost? Will it have a personal/social benefit?
- Conservation initiatives must be culturally sensitive

Arguments for Protecting Biodiversity

- **Aesthetic**
    - Would you like to live in a world without nature?
- **Ethical**
    - Do we have the right to drive species to extinction?
    - Obligations to future generations
- **Economic**
    - Pharmaceuticals derived from nature
    - Estimated $33 trillion in ecosystem services provided by the earth annually
    - Commercial and sport fisheries

The Protection of Biodiversity

- **To protect something, you must understand it.**
- Protection requires:
    - Understanding what diversity is and why it is important
    - How it is created **(speciation)**
    - How it is maintained **(coexistence mechanisms)**
        - Predation, competition, etc.
    - How it is lost **(extinction)**

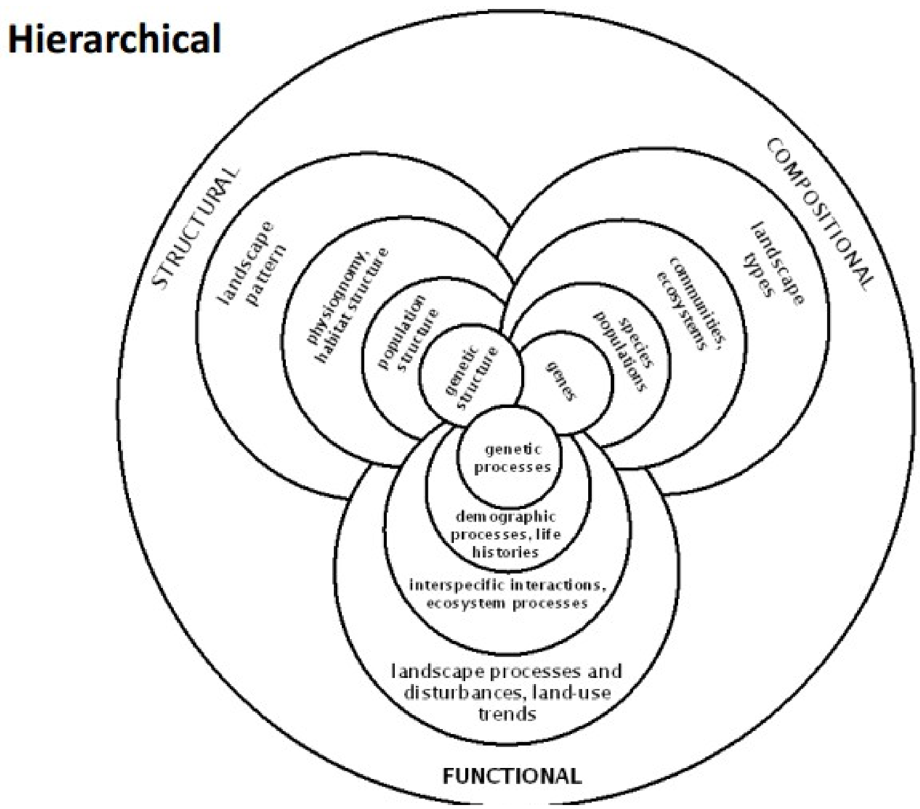
Defining Biodiversity

- “The sum total of all living things” and their interactions.
- **Needed:** A precise quantitative measure
- **Currently:** “A bewildering array of diversity indices” (Magurran 1988)
    - Even the best indices have something lacking

- Inability to predict human impact
- Science is about generating models, getting information to be able to generate models to predict an outcome using these models
- Biodiversity and relationships are too complex to actually predict

Defining Biodiversity

- **Composition**: the genes, species, and habitats found at a time and place (what is there/how many?)
- **Structure**: the vertical and horizontal arrangement of physical space (snags, riffles, litter layers, canopy height...)
- **Function:** the processes that affect (and are affected by) biodiversity (biochemical cycling, invasion, natural selection). Usually hierarchical.



- Nested effect – what happens in the outside circles will affect those within
  - What affects landscape will affect genetics
- Genetic process – drives evolution and sustainability
  - What affects landscapes will affect genetics

Components of Biodiversity

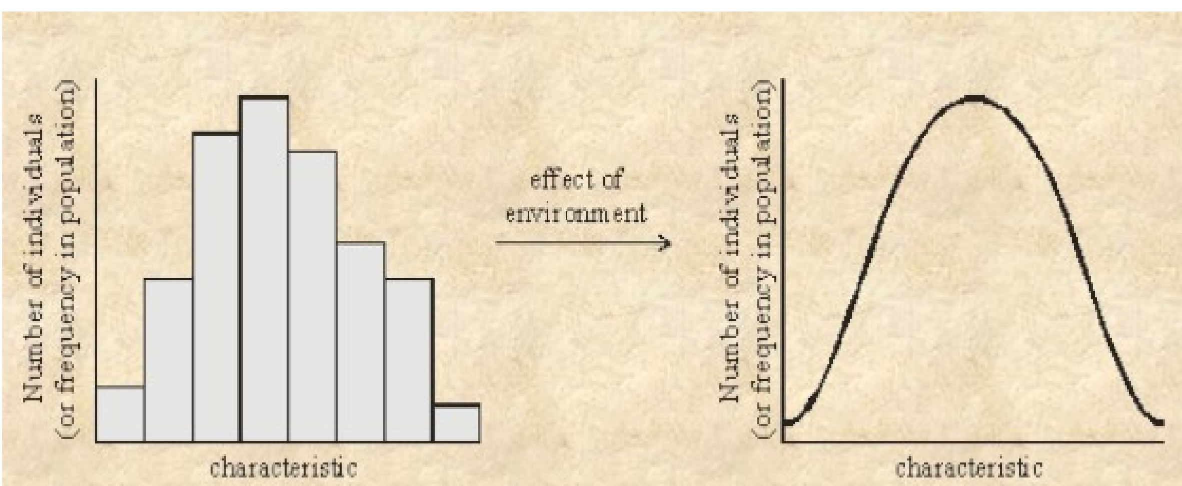
- Genetic diversity
- Population-level diversity
- Human cultural diversity
- Species diversity

Genetic Diversity

- Ultimate source of biodiversity (what causes evolution, speciation, and future changes)
- Evolution works with genes
- Allelic diversity of genes (many different combinations)
- Possible combinations are enormous
- Variability as the source for future changes
- New techniques – new era for genetic studies of biodiversity.
  - DNA barcoding, genetic modification, etc.

Population Level Diversity

- A group of individuals of a species living in an area at the same time
  - Often a normal (bell-shaped) distribution
  - May shift – for example, height
  - Environmental characteristics may shift this curve
- Variability as a source for speciation
- Variability as the source for future changes

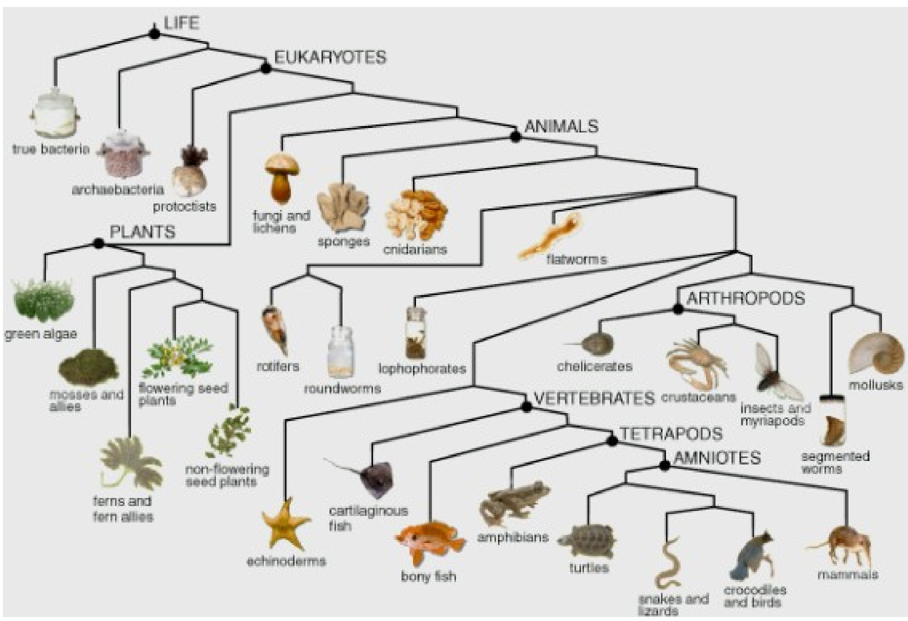


Cultural Level Diversity

- Unique viewpoints and values placed on biodiversity
  - Different solutions and perspectives on the challenges of making a living and coexisting
    - We must understand culture to suggest changes to conservation methods
  - Aphrodisiacs – rhino horn, Spanish fly
- Different Impacts
  - Some cultures are worse on the environment than others, in different ways
- 6526 languages; 50% at risk within the ethnosphere

Species Diversity

- **Species** – a group of actually or potentially inter-breeding natural populations that are reproductively isolated from other such groups
- 2 million catalogued species; 10-50 million in total
- **Phylogenies** – hypothetical descent-histories of a group of species from some common ancestor.



Conservation Genetics

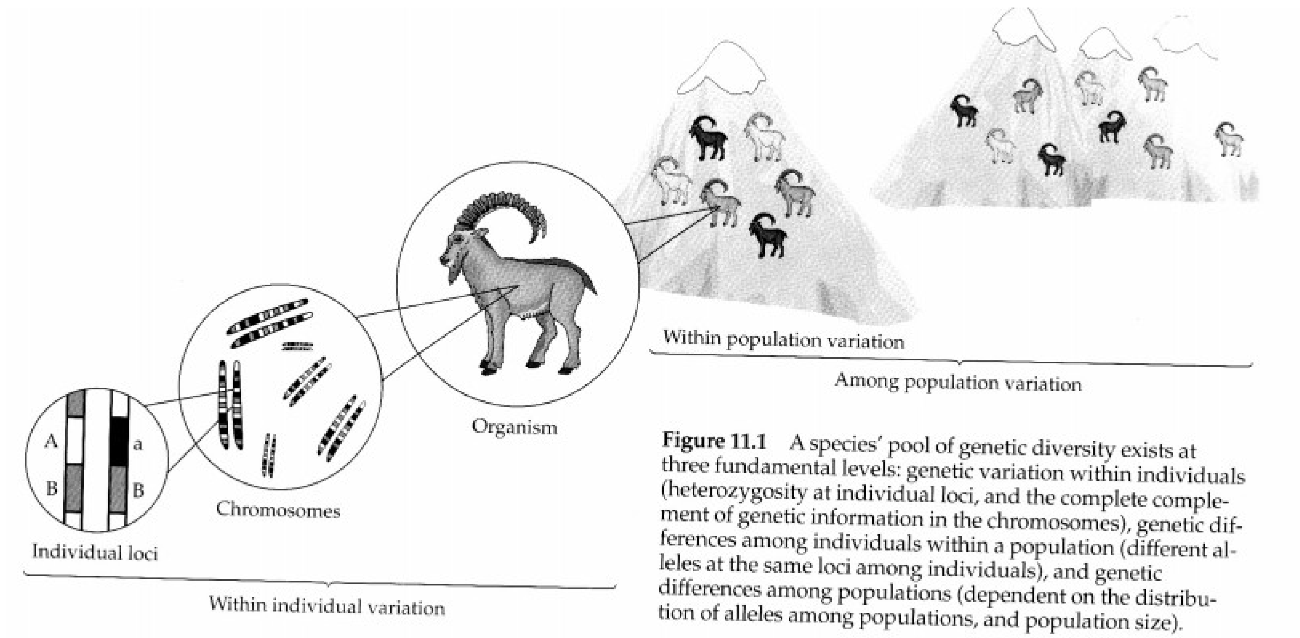


Figure 11.1 A species' pool of genetic diversity exists at three fundamental levels: genetic variation within individuals (heterozygosity at individual loci, and the complete complement of genetic information in the chromosomes), genetic differences among individuals within a population (different alleles at the same loci among individuals), and genetic differences among populations (dependent on the distribution of alleles among populations, and population size).

- Genetic diversity of a species exists at 3 levels
    - **Genetic variation within an individual**
        - Effects things at the individual level
    - **Genetic variation at a population level**
        - Differences among individuals within a population
    - **Genetic variations among populations of a species**
        - Differences between populations
        - Example – salamander populations

Within Individuals

- The number of genes in an individual varies depending on the species
- Within a species, genes usually exist as several forms
    - We are diploid, inherit one of each allele from each parent

One gene – 4 alleles C, c, c^h, c^{ch}

Possible genotypes	CC, Cc^{ch}, Cc^h, Cc	$c^{ch}c^{ch}$	$c^{ch}c^h$, $c^{ch}c$	c^hc^h, c^hc	cc
Phenotype	Dark gray	Chinchilla	Light gray	Point restricted	Albino

- Coat colour (rabbit) – 1 gene, 4 alleles, each individual has 2 alleles

Two genes – 2 alleles each B b and E,e

(A) Black labrador (*B_E_*) (B) Chocolate labrador (*bbE_*) (C) Yellow labrador (*_ _ee*)

- Labs – 2 genes, one for colour and one for which colour is expressed
  - Homozygous – same allele
  - Heterozygous – different alleles
- Specific combinations of alleles can result in one individual being "more fit" than another
- Phenotype = Genotype + Environment

•P = G + E

- Why focus on individual genetic diversity?
  - Natural selection
    - Natural selection acts upon allelic heterozygosity within an individual
  - Inbreeding
    - The level at which genetic problems associated with inbreeding are apparent – causes a decrease in fitness
  - Captive breeding
    - Knowledge of genotypes/phenotypes is important in captive breeding – genetic diversity is important!

    - Estimations of population variability (we can only predict population variability from individual variability)
        - We measure genetic variability in individuals and use it to estimate the variability in the population

Population-level diversity

- Persistence over time
    - How is a species going to respond/how quickly to change?
- Reflect evolutionary history of the population
- Shape the population's potential for adaptation to changing enviromnments
- Genetically-based plasticity in life history characteristics important in restoration/reintroduction
- Example – Stickleback
    - A little fish with 2 phenotypes: Armoured and unarmoured
        - Armoured: Grow slowly, less young, high defence as adults – best where adults are predated
        - Unarmoured: Grow quickly, more young, little adult defence – best where the young are predated
    - A difference in environment affected the phenotype
        - Unarmoured prevalent in lake ecosystems
        - Stickleback poisoned out of the lake in 1982
        - In 1990, armoured (ocean) stickleback came into the lake
        - The armoured young were eaten by dragonfly larvae
        - Unarmoured made a population comeback
        - Tradeoff between defence and reproduction
            - Low armour – more resources for offspring (high predatory force on young)
            - High armour – more resources for defence, best when there is more predation on adults. Less offspring produced.
    - When reintroducing a species, make sure you have the right morph!

Within Population versus Among Population Diversity

- Gene Pool - Relative frequencies of all alleles across all members of the population
- Mean heterozygosity – average number of each individual multi-loci heterozygosity
    - Woodridge is highest
- Polymorphic – more than one allele

- Litchfield only has one polymorphic gene, lowest heterozygostity
  - To preserve this population we may want to increase its heterozygosity, especially if the alleles they were missing were beneficial for survival in a stressful environment

$$H_T = H_p + D_{PT}$$

H_T = total genetic variation (heterozygosity)

H_P = average diversity within populations

D_{PT} = average divergence among populations surveyed

- Hp usually makes up most of biodiversity
- How is this diversity spatially distributed? Where to preserve?
  - Compare to other species, why is it the same/different
  - Woodpeckers are very site-specific, so the divergence between populations (Dpt) tends to be higher than other birds
- As we increase habitat fragmentation, we increase Dpt
- Mobile animals tend to have a lower Dpt
  - Birds, insects – less impacted by habitat fragmentation

Eg Red-cockaded woodpecker
H_T = 7.8%, 14% of which was D_{PT} and 86% of which was H_P

TABLE 11.4 *Mean Total Heterozygosity (H_T) and Proportion Due to Among-Population Differentiation (D_{PT}) in Several Major Taxonomic Groups*

Taxon	H_T	Number of species	D_{PT}	Number of species
Vertebrates				
Fishes	5.1%	195	0.135	79
Amphibians	10.9%	116	0.315	33
Reptiles	7.8%	85	0.258	22
Mammals	6.7%	172	0.242	57
Birds	6.8%	80	0.076	16
Invertebrates				
Insects	13.7%	170	0.097	46
Crustaceans	5.2%	80	0.169	19
Molluscs	14.5%	105	0.263	44
Others	16.0%	15	0.060	5

Alpine Ibex vs White-tailed Deer

- Ibex
  - Only on the tops of mountains
  - Increased proportion of Ht from Dpt
- White-tailed Deer
  - Mobile, large uniform distribution
  - Decreased proportion of Ht from Dpt
- Still the biggest concern for both is Hp

Genetic Variability

TABLE 11.5 *General Correlates of Genetic Variation among Population*

1. Genetic variation within species will be positively correlated with population size.
2. Genetic variation will be positively correlated with habitat area.
3. Genetic variation will be greater in species with wider ranges.
4. Genetic variation in animals will be negatively correlated with body size.
5. Genetic variation will be negatively correlated with rate of chromosomal evolution.
6. Genetic variation will be positively correlated with population size across species.
7. Genetic variation will be lower in vertebrates that in invertebrates or plants.
8. Genetic variation should be lower in island populations than mainland populations.
9. Genetic variation will be lower in endangered species than nonendangered species.

- What genes should we be looking at in terms of conservation and natural selection?
- We have no baseline for what the distribution of genetic diversity should be for a healthy/stable population
  - Cheetahs have a very similar Major Histocompatibility genes, so they can easily accept donor organs
    - This genetic similarity is because of a bottleneck event that happened ~10,000 years ago
    - Is this a problem? We can't decide on a small timescale.
    - In changing conditions they may not be able to adapt
    - Which genes are important in survival of the species?
      - MHC genes are related to immune system capacity. With little genetic variation, it is expected that a disease could wipe out the whole population.
      - Lions, for example, got infected by feline distemper, but genetic variability meant that only 30% of the population died.

Changes in Gene (Allelic) Frequencies

- **Gene flow**
  - Migration between populations and breeding
    - Populations must be allowed to mix! This is the main contributor to change in gene frequencies
  - Use markers in junk DNA to determine if this has occurred – genetic markers are generally neutral to natural selection
- **Genetic drift**
  - Random fluctuations of gene frequencies due to chance alone
- **Unequal family sizes or number of matings**
  - Different animals will produce more or less offspring to the next generation (natural selection)
  - To maximize genetic diversity you would want all animals contributing equal numbers of offspring
  - Can estimate the population size needed to maintain x% of genetic diversity over x# of years
- **Reductions in population size**
  - Problems with small populations
    - **Demographic stochasity –** Variability in population growth rates arising from random differences among individuals in survival and reproduction within a season
      - Eg. Flood drowns 5 individuals, genetic diversity is lost
    - Decrease in diversity over time, this drop is faster with smaller populations
    - Impact of stochastic events is more pronounced
      - **Stochastic event** – random differences among individual survival
      - Example – all babies in a nest die in a storm
    - Genetic drift has more of an impact (**outbreeding depression** – breeding out characteristic that make an individual more fit)
    - **Inbreeding depression** – loss of fitness due to inbreeding
      - Inbreeding increases the chance of homozygosity of lethal alleles

Genetically Effective Population Size (N_e)

Size of an idealized population that would have the same amount of inbreeding, loss of heterozygosity or random gene frequency drift as the population under consideration - stable

$N_e = (4N_m \times N_f)/(N_m + N_f)$

N_m = number of breeding males
N_f = number of breeding females
eg – census (N) of 500 animals, all breeding, 1:1 sex ratio has a
$N_e = (4\text{x}250\text{x}250)/(250 + 250) = 500$

But if only 450 females bred with 50 males then
N_e=(4x50x250)/(50+450) = 180

Effect of Variation in Progeny Number

$$N_e = k(Nk-1)/[V_k + k(k-1)]$$

K = number of surviving progeny
V_k – variance in number of progeny surviving

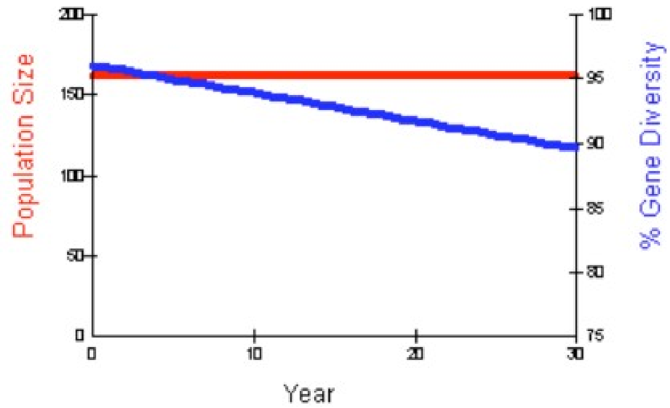
- Larger variance reduces Ne

Vancouver Island Marmot

2010. Genetic Summary Table:

	Current	Potential
Founders	40	0 additional
Founder genome equivalents	14.29	23.58
Founder genome surviving	23.58	23.58
Gene diversity retained	0.965	0.9788
Population mean kinship	0.035	
Mean inbreeding	0.0007	0.001
Ne / N	------	-----
% of pedigree known	100	-----

If we wish to maintain 90% GD over 20 years we need:
Population Size Needed to Meet Goals Needed = 102
Program Objectives: 90% Gene Diversity at the end of 20 years
Assuming Generation Length = 4
Maximum Potential Population Growth Rate = 1.32
Current Population Size = 92.0000
Current Effective Size = 32.2000
Ratio of Ne/N = 0.35
Maximum Allowable Population Size = 110.0000



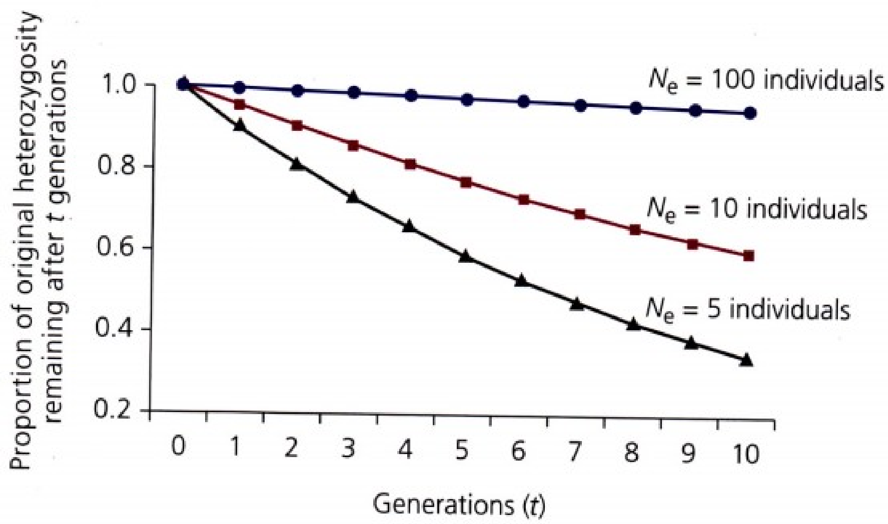


Figure 7.4 Proportion of original heterozygosity (H_0) that remains after *t* generations. As the effective population size (N_e) increases, heterozygosity is lost more slowly.

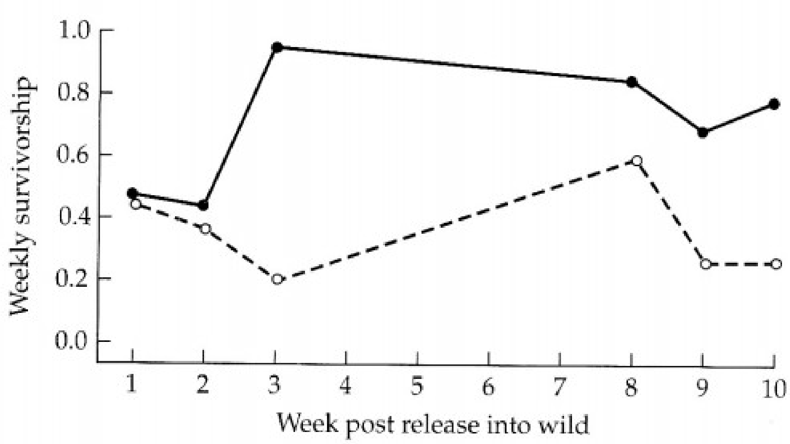
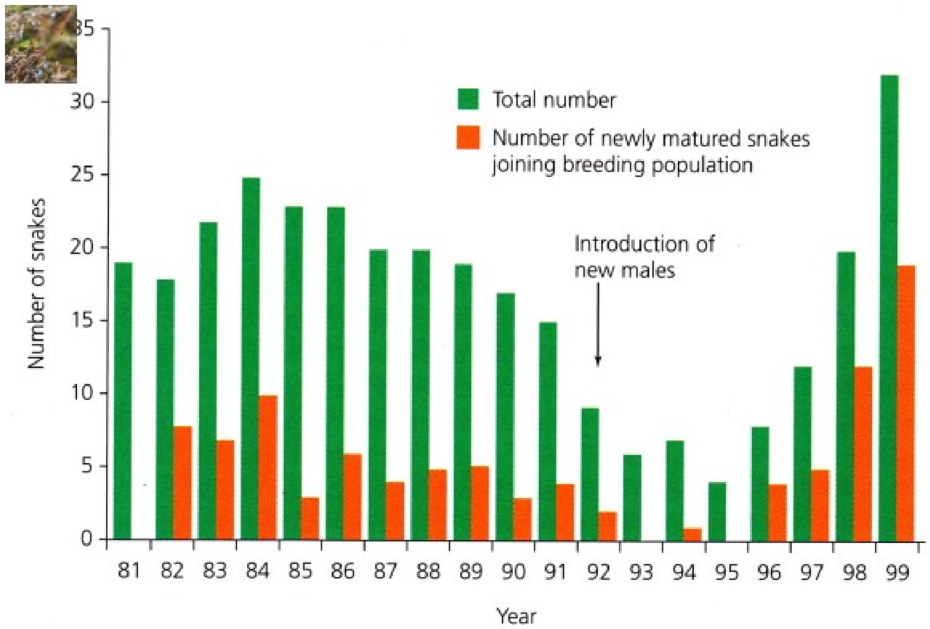


Figure 11.8 Inbred white-footed mice, (*Peromyscus leucopus*) (open circles), had lower survivorship than outbred individuals (solid circles) after release into the wild. Wild-caught mice were used to found an inbred and outbred line, and descendants of these mice were released back into the wild and followed for 10 weeks. (Modified from Jimenez et al. 1994.)



B

Figure 7.3 Genetic rescue of a small, isolated population of (A) the adder *Vipera berus*. (B) Annual censuses between 1981 and 1991 revealed a declining population with small numbers of new adults recruiting into the breeding population each year. A 1992 translocation of 20 adult males into the population led to dramatic population recovery and improved recruitment of new adults into the breeding population, with a time lag of roughly four years, as discussed in the text. Translocated individuals are not included in the population estimates. After Madsen et al. (1999).

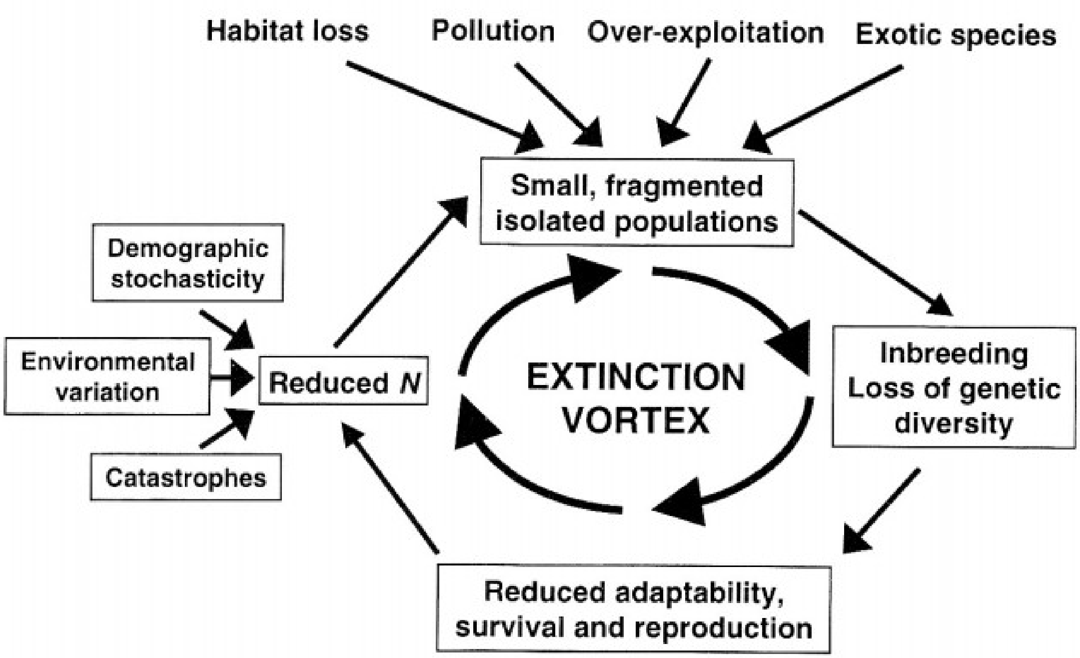


Fig. 2.3 The extinction vortex. This describes the possible interactions between human impacts, inbreeding, loss of genetic diversity and demographic instability in a downward spiral towards extinction.

- Common with small populations getting smaller and smaller
- ***Know for the exam, each part in detail!!!!!***

What Is a Species?

- Do we conserve populations? Species? Sub-species?
- ESU – evolutionary significant units
  - Accepted definition of a distinct population
  - Must be substantially reproductively isolated
  - Must represent an important component of evolutionary legacy of the species – contributes to evolutionary/genetic diversity of the species as a whole
- Legislation protects "species"
  - Language is unclear – works with species and ESUs
  - Under ESA, hybrid subspecies are not protected
    - If a species is no longer protected, their habitat won't be either
      - Eg. Florida panthers bred with Texas cougars
      - Eg. Red Wolf – captive breeding and reintroduction, but very small population size. Healthy wild population of red wolves in Canada – genetics do not agree that they are the same species. Should we treat them as a separate population?

Lecture 4 - Guest Lecture: Conservation Genetics with Alex Smith

Three Categories of Conservation Genetics Questions

1) How much genetic variation is available in endangered and threatened species for adaptation to future environmental change?
2) How much genetic variation is available in endangered and threatened species for adaptation to future environmental change?
3) What is the unit or group to be conserved?

- Most species are invertebrates – most of these are insects.
  - Most of these species have no name.
  - Without names, we can not accomplish either of the first two categories of conservation genetics.
  - More effort (a proportionate amount) needs to be spent on the conservation genetics within the 'taxonomic impediment'.

Taxonomic Impediment

- " 'Issues' currently obstructing progress in taxonomy"
- "Lacking the taxonomic expertise to adequately describe the biodiversity on this planet"

- “To increase our base of taxonomic expertise to handle the biodiversity that exists yet to be described”
- “To get those already trained as taxonomists to publish their findings”
- “Canada’s constrained capacity to analyze biodiversity information impedes the nation’s ability to achieve the goals set out in these policy instruments.”
- “This stagnation constrains Canadian research scientists, biasing research activities away from costly endeavours such as molecular analyses, remote field work, and radiotelemetry.”

Species Problem

- What precisely is a species? (Ontology)
    - Definitions (being and reality)
    - What a species is.
- What precisely is in a species? (Epistemology)
    - Concepts (knowledge and theory)
    - What we might know about a species

Focus of study

- Measured by concept, methodology, or taxa, the publications in the journal Conservation Genetics are directed towards sub-specific problems (here’s a hint: use microsatellites to look at the genetic diversity of fish – you’re in!).
- These problems are only tractable when you know what the “it” is that you are dealing with.
- Much of conservation (and the world) is not in this “comfortable” situation.

Northern Entomological Research in Canada

- Organized entomological research in northern Canada began in 1947 as a joint project of the Defense Research Board, Department of National Defense, and the Entomology and the Botany and Plant Pathology divisions, Department of Agriculture.
- The Northern Insect Survey dealt with systematics, distribution, relative abundance; and ecology of biting flies and other insects, by the Systematic Entomology and Botany units.

Microgastrinae at Churchill, Manitoba, Canada

- 79 species of Microgastrinae from 11 genera.
- One new record for the Nearctic and 9 species recorded for the first time in Manitoba.
- Collecting efforts between 2005 & 2007 revealed a total of 64 species.
- Comparing 21st century Churchill microgastrine fauna to Churchill represented in specimens collected before 1960
    - Only 11 of these (17%) overlapped with species collected at Churchill before 1960.

    - Fourteen of the 30 species(46.7%) collected before 1960 were absent from the recent collections
    - Little overlap between past and present.
    - Present is more diverse (sampling methodology).
    - Shared category is widely distributed.
    - Present-only is very southern affiliated.
    - Historic-only specimens were not seen in either northern or southern collections.
    - Historic-only specimens were more similar to those collected to the north and east.

<u>Lecture 5 – Inventory of Biodiversity</u>

Challenge: Inventory

- **Species** - actually or potentially interbreeding natural populations that are reproductively isolated from other groups
    - Strictly biological – can breed and produce viable, fertile young
    - 2 million categorized – 10-50 million potentially
    - Too many to individually protect
- **Phylogenies** – hypothetical descent-histories of a group of species from some common ancestor
    - Much of the diversity is unexplored
    - 300 new species are classified every day
- How do we protect things we cannot identify?
    - Historically - Linnaeus – biological, morphological classification
        - Each species has two names - (genus and species)
    - Now DNA barcoding
        - Uses a short genetic marker in an organism's mitochondrial DNA to identify relatedness among species
        - Mitochondrial DNA has a relatively fast mutation rate
- However, even if we identify species, there are too many for us to individually protect and manage
    - **Charismatic Megafauna** can act as umbrella species – by protecting their habitat we can protect multiple other species
    - Mammals <6kg will benefit from protecting ecosystems
    - Mammals >6kg need ecosystem protection as well as conservation management/protection plans

The Challenge of Inventory

- Too many species to protect and manage (SARA – individual management plans)
- **Redundancy**
  - We classified differences in diversity necessarily indicative of meaningful ecological differences
- **Gaps**
  - Knowledge base is not big enough
  - Management strategies are only as effective as our knowledge base

Inventory Alternatives

- Community and Ecosystem Classification
  - Old emphasis on species
  - New emphasis on species aggregations
  - Assumption: Community conservation captures multiple species, and the processes that maintain them
    - What are these processes?
      - We need to know which these processes are in order to protect them
    - What mechanisms create, maintain, and explain the loss of biodiversity?

Ecozone Classification

- There are eight biogeographic realms (ecozones)
  - Ecozones delineate large areas of the earth's surface in which organisms have been evolving in isolation over long periods of time.
  - Isolated by geographic barriers
  - Isolated through continental drift
  - Within each of the ecozones are biomes which are identified on the basis of the dominant type of vegetation

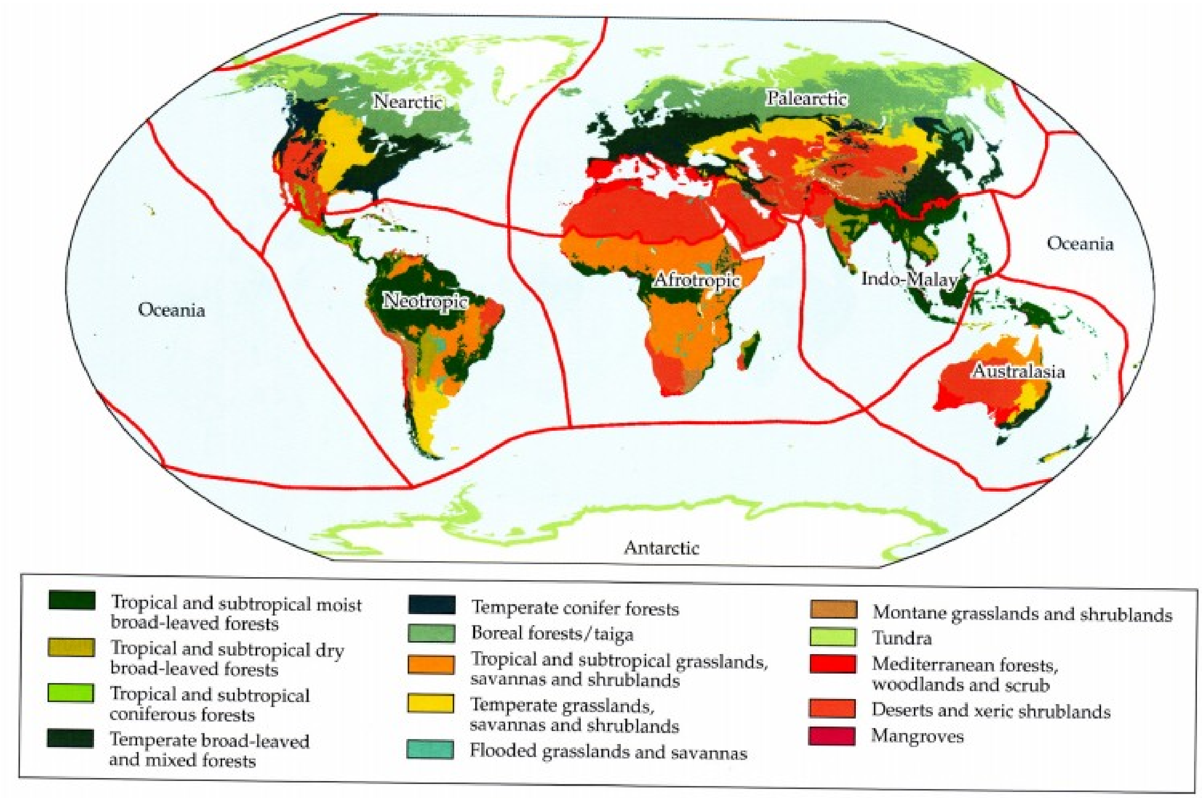


Plate 1 The eight biogeographic realms of the world, with the 14 terrestrial biomes distributed within these. (Courtesy of WWF–US, GIS map provided by J. Morrison.) [2]

- ***********KNOW THE EIGHT ECOZONES!!!*****
  - Biomes can be present in more than one ecozone, though they have different evolutionary histories
  - Biomes change along a gradient of precipitation and temperature
- **Ecoregion –** a new classification of biomes
  - 867 in the world
  - A relatively large area containing a distinct assemblage of natural communities and ecological conditions characterized by a widespread assemblage of species
  - Most widespread and comprehensive classification
- Made possible by satellites and computers
  - Geographical Information Systems (GIS)
  - Landfast photos
  - Sub-meter GPS mapping

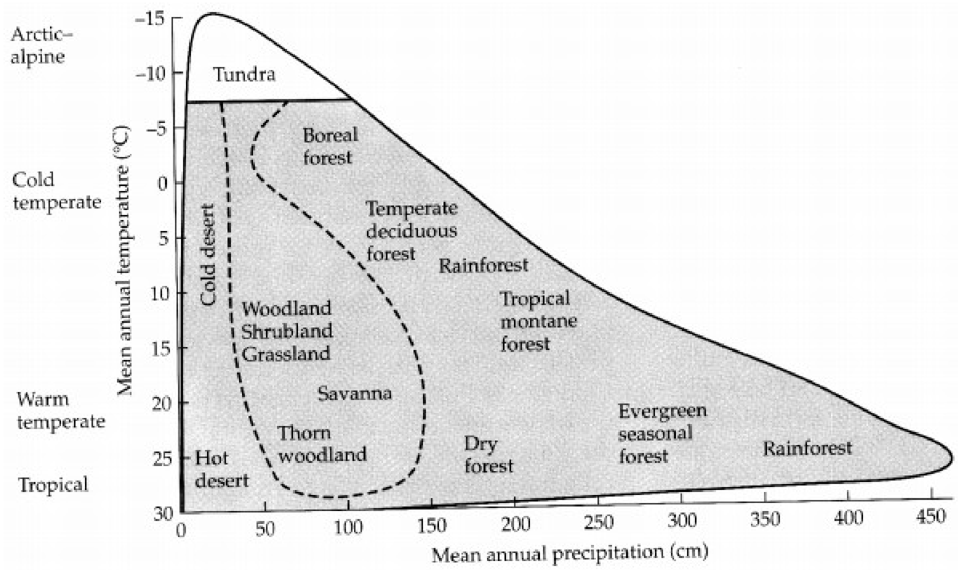


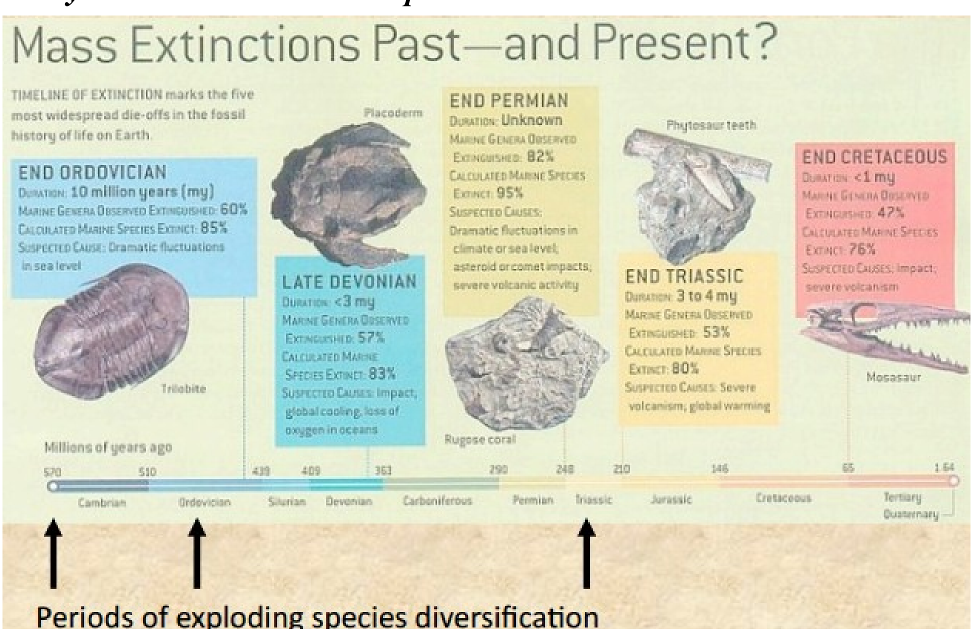
Figure 2.4 Biomes and climate. Distributions of the major biomes are plotted on axes of mean annual precipitation. Within the region bounded by the dashed line, factors such as seasonality of drought, fire, and grazing strongly affect which type of vegetation is present (Modified from Whittaker 1970.)

Challenge: Extinction

- We may be perched on the edge of a massive extinction event, associated with global-level environmental change
- Climate change is a priority for conservation
  - Have such events occurred before, and under what circumstances (fast vs. Slow)?
  - How does diversity respond – adjustments via speciation or permanent reductions?
  - Are these past extinctions and adjustments relevant for understanding future levels of diversity?

Timelines: Speciation vs. Extinction

- ***Diversity is the balance between speciation and extinction***



- 5 massive extinctions have occurred before
- Extinctions tend to be followed by pulses in speciation
- The frequency of extinction has gradually slowed with time

- Massive Extinction Events
  - Very rare – has occurred 5 times in 3 billion years
  - All mass extinctions were caused by something that disrupted global climate patterns, disrupting photosynthesis
- Massive Speciation Events
  - Triggered by:
    - Mass extinctions (recovery – 10 million years)
      - Background extinction rates are about 2-5 families per million years
    - Increasing separation of land masses
    - Evolution of new forms and types of species interactions (eg. Angiosperms, pollinators, flight)

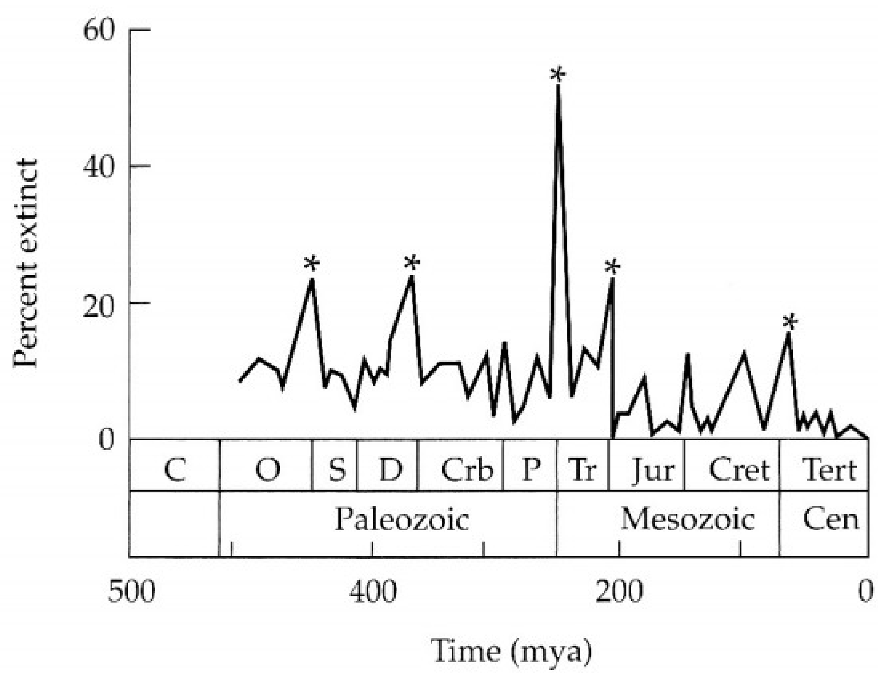
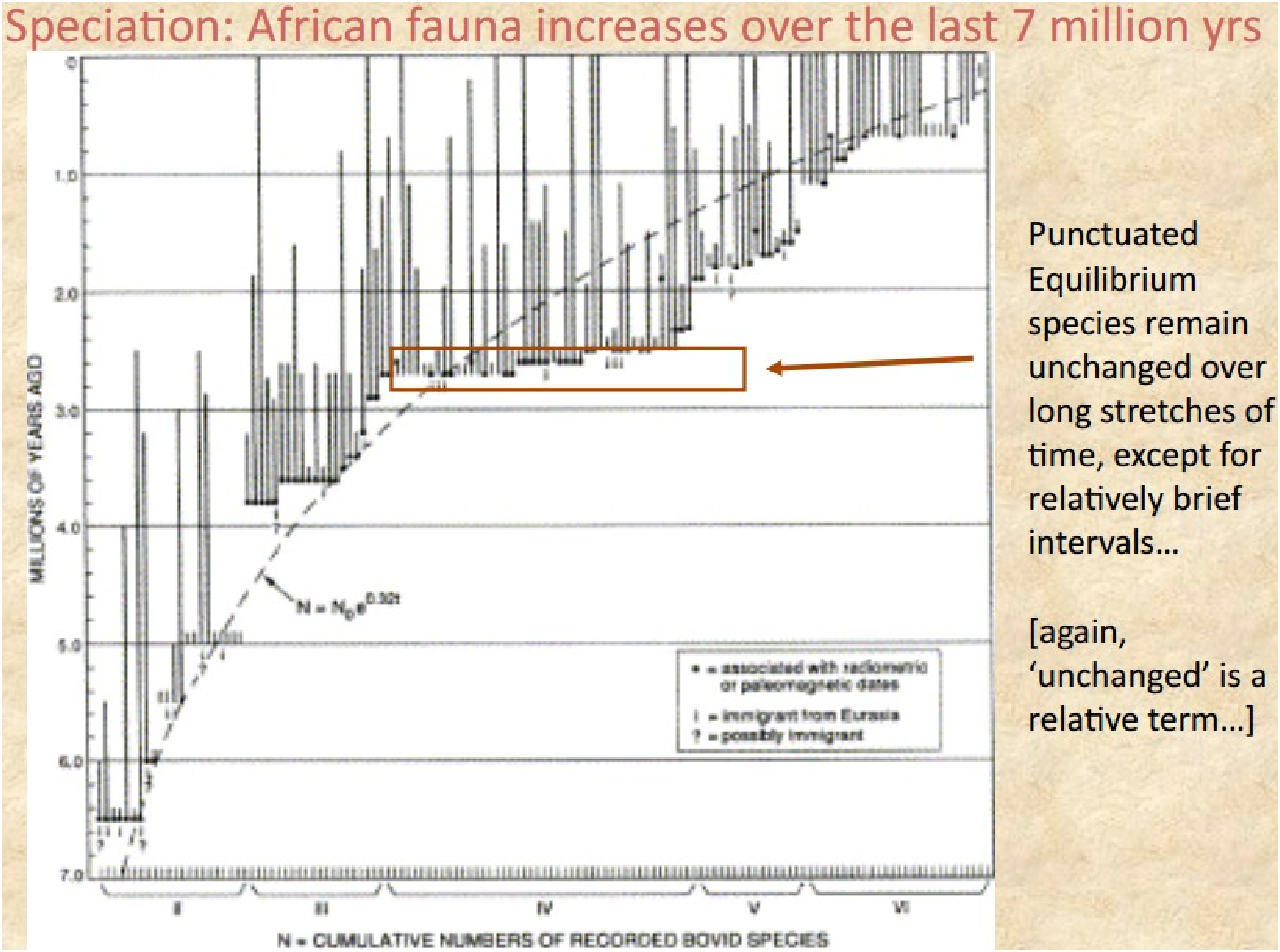


Figure 2.7 Extinctions of families through geologic time. The five hisrtorical mass extinction events are marked with an asterisk.

- Which is more important: Gradual or Explosive extinction and speciation?
  - In terms of diversity, they are equal (in creating and maintaining)
- **Punctuated Equilibrium:** Species tend to remain steady over a long period of time, except for brief intervals of explosive speciation



A Sixth Mass Extinction Event?

- If we're on the verge of a mass extinction event:
    - How will it occur (gradual, episodic)?
    - Which species will be vulnerable?
    - Can the past help us to anticipate the future?
- Are we causing the sixth mass extinction?
    - Current loss of species is about 1000x the rate we see in fossil records

IUCN – International Union for Conservation of Nature

- Red List of Endangered Species
- Goal: To provide information and analysis on the status, trends, and threats to species in order to inform and catalyse action for biodiversity conservation

<u>Lecture 6 – Speciation</u>

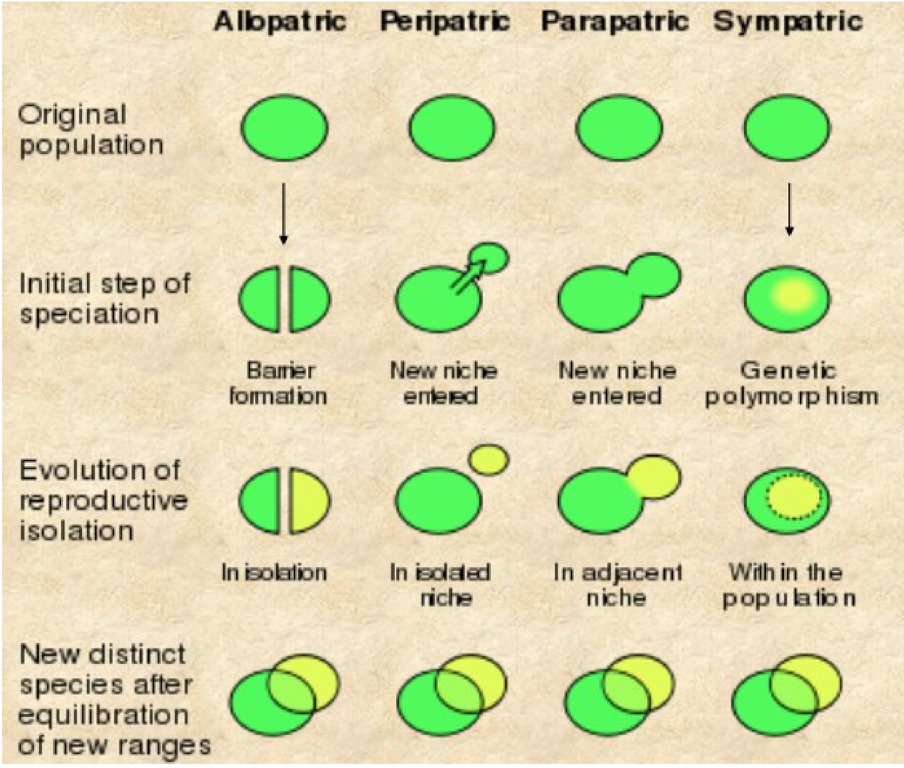
- Not all rare species are "created equal"
- Not all species are similarly vulnerable to the effects of global environmental change
- Determining extinction vulnerability starts with:
  1) Understanding how species are created
  2) Understanding how diversity is created
  3) Understanding how diversity is maintained (or not)

Effects on Genetic Makeup

- Genetic Drift – random chance can create new populations (stronger effect on smaller populations)
- Population Bottlenecks – drastic decrease in population reduces available alleles
- Founder Effect – only alleles in parents population are available (small founder populations have fewer diversity of alleles)
- Inbreeding Depression – closely related parents produce less fit offspring
- Outbreeding Depression – parents too unrelated (getting to the point of being separate species) will also have less fit offspring
  - Ideal – same species, but not related.

Challenge: Speciation

- What are the various types of speciation?
  - 4 Geographic methods of speciation:

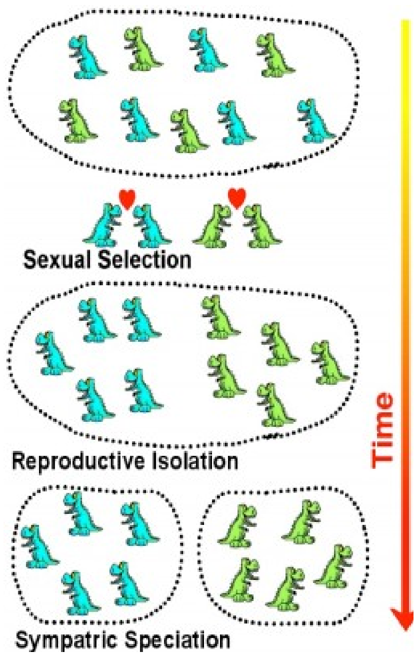


- **Allopatric Speciation**
  - Population splits into two geographically isolated populations (barrier isolation)
  - Independently undergo genetic drift, dissimilar selection pressures; different mutations arise and the species become separate
  - Even if reintroduced, reproductively isolated – if they can reproduce, their offspring lose fitness.
  - Example – the Hoary and Vancouver Island Marmot
- **Peripatric Speciation**
  - A sub-form of allopatric speciation: *very small* population enters a new niche that is separated from the main population
  - Key issues to do with the small population: bottlenecks, founder effects, genetic drift
  - Peripheral populations – no gene exchange with main population
  - Inbreeding/outbreeding depression
  - Example – Grizzly bears more genetically diverse, so polar bears are more vulnerable to extinction.
- **Parapatric Speciation**
  - Only partial separation of the zones of the two diverging populations afforded by geography – niche adjacent to niche of main population
  - Individuals may come into contact, but reduced offspring fitness leads to selection of mechanisms that prevent interbreeding
  - Example – Salamanders migrating around a valley, populations on the edges of

migration develop so differently that when they meet on the other side of the valley they can no longer breed.

- Ring species

- **Sympatric Speciation**
  - Two or more descendant species from a single ancestral species all occupying the same geographic location
  - Mechanism: individuals switching to different microhabitats, creating fitness differences that become reinforced by sexual selection



Endemism

- The byproduct of peripheral speciation, by whatever mechanisms
- A species found in one area but nowhere else
  - Example – Splendid Fairywren (Australia)
  - **Biodiversity Hotspots**
    - Areas with a high concentration of endemic species, experiencing rapid habitat loss

- Species-rich Hotspots with high endemism:
  - 1.4% of land area
  - 44% of vascular plant species
  - 35% of terrestrial vertebrate species
- However:
  - These areas support 20% of the human population, which is growing at 1.8% per year (1.3% worldwide)
  - Each hotspot has already lost 70% of its vegetation

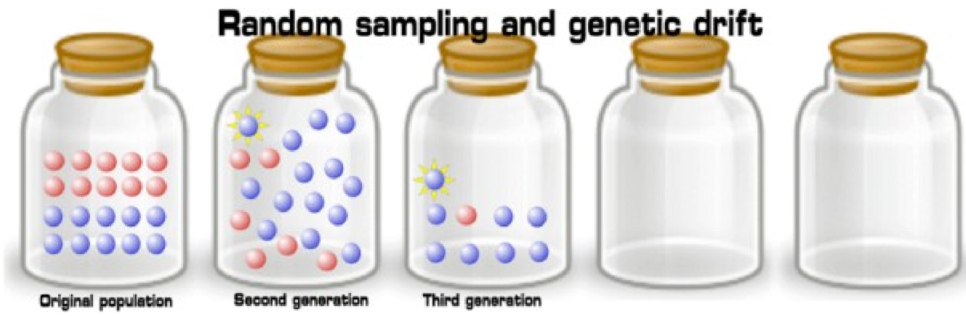
Alwyn Gentry

- Discovered hundreds of new plant species in South America
- Mountainous area supported dozens of its own endemics (1985)
- Deforested (1986)

- Does speciation occur at equal rates and by similar mechanisms across the planet?
- Do different types of speciation result in different degrees of sensitivity to extinction?
- Can speciation occur rapidly in response to modern-day global environmental change?

Important Effects on Genetic Makeup of New Populations

- **Genetic Drift**



- **Population Bottlenecks**
- **Founder Effects**
- **Inbreeding/Outbreeding Depression**

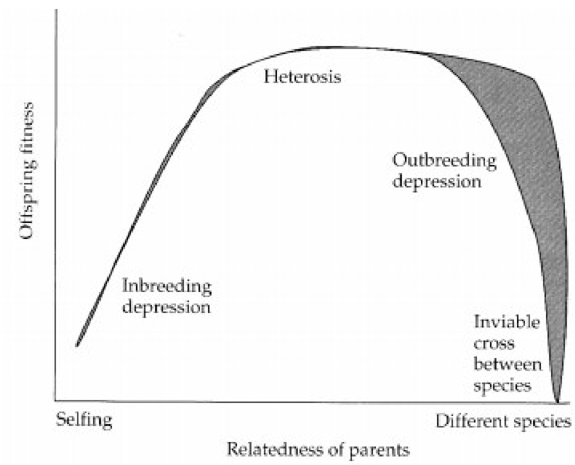


Figure 11.9 Offspring fitness is influenced by the degree of relatedness of parents. Closely related parents produce inbred young that are less fit than those of unrelated parents of the same species, leading to "inbreeding depression." When parents are unrelated, fitness rises yielding hybrid vigor or "heterosis." As parents are more distantly related, some decline in fitness may occur (outbreeding depression) and usually at some point, offspring from crosses between species are far less fit, even to the point of inviability.

<u>Lecture 7 - Biodiversity questions</u>

Biological Communities

- Determining extinction vulnerability starts with:
    1) Understanding how species are created
    2) Understanding how diversity is created
    3) Understanding how diversity is maintained (or not)

Diversity of biological communities

- Evenness/Abundance

    - Highest value of evenness when all species are equally abundant
- Species Diversity Indices
    - Take into account evenness, abundance, species richness
    - Often used to assess impact of pollution, etc. on an ecosystem (usually seen as an increase in dominance of one species and a decline of others – an overall loss of diversity)

Species Richness

- Defined by the species found within a community (or families)
- Species richness of community/area

Beta Richness

Diversity of biological communities

- Evenness/Abundance

Current Patterns of Diversity

Species Richness – Area Relationships

Lecture 8

Lecture 9

<u>Lecture 10 – Threats</u>

Threats to Biodiversity

- Habitat change
- Climate Change
- Invasive species
- Over-exploitation
- Pollution (Nitrogen, Phosphorus)

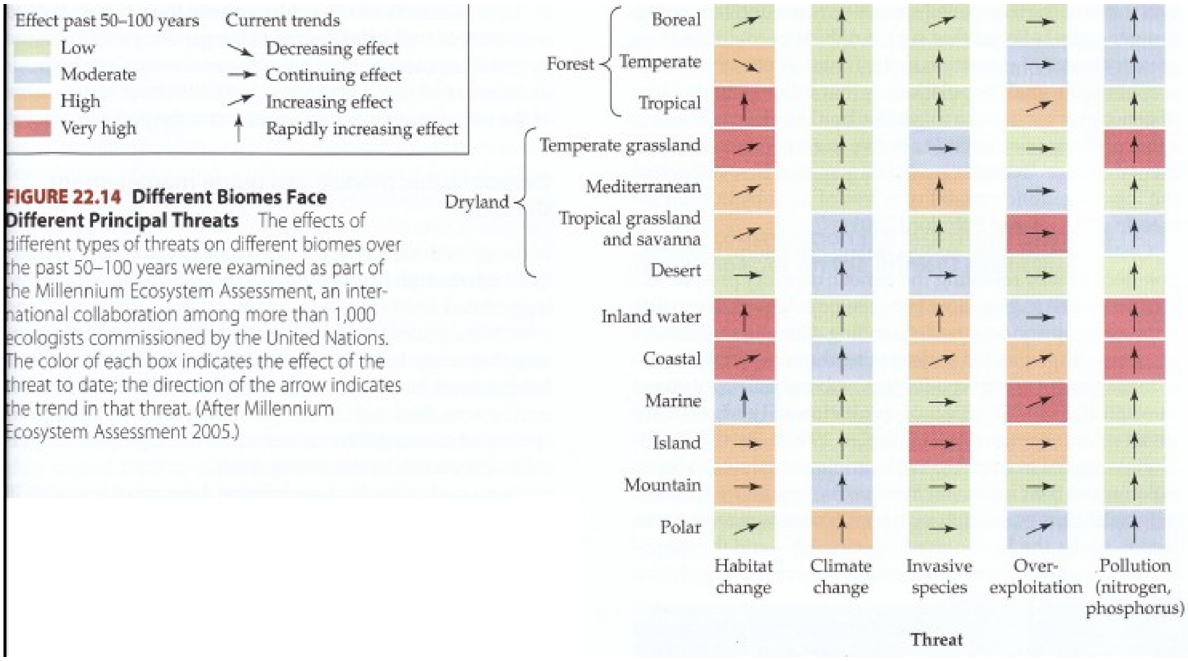


FIGURE 22.14 Different Biomes Face Different Principal Threats The effects of different types of threats on different biomes over the past 50–100 years were examined as part of the Millennium Ecosystem Assessment, an international collaboration among more than 1,000 ecologists commissioned by the United Nations. The color of each box indicates the effect of the threat to date; the direction of the arrow indicates the trend in that threat. (After Millennium Ecosystem Assessment 2005.)

- Regions less accessible to people are less affected

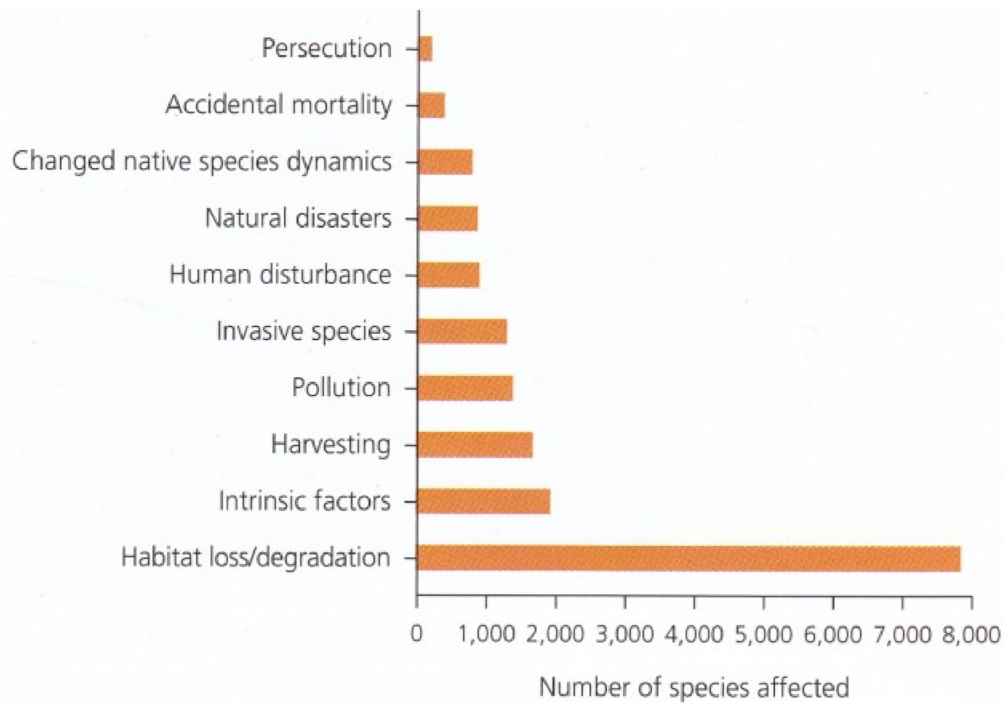


Figure 9.1 Threats to species in the IUCN threatened categories (CR, EN, and VU). Individual species may be affected by multiple threats, and the figure excludes species with unknown threats. Data are from IUCN (2009a).

Habitat Loss/Fragmentation

- ***The biggest threat to endangered species***
    - The next biggest impacts are intrinsic factors (inbreeding, genetic drift)

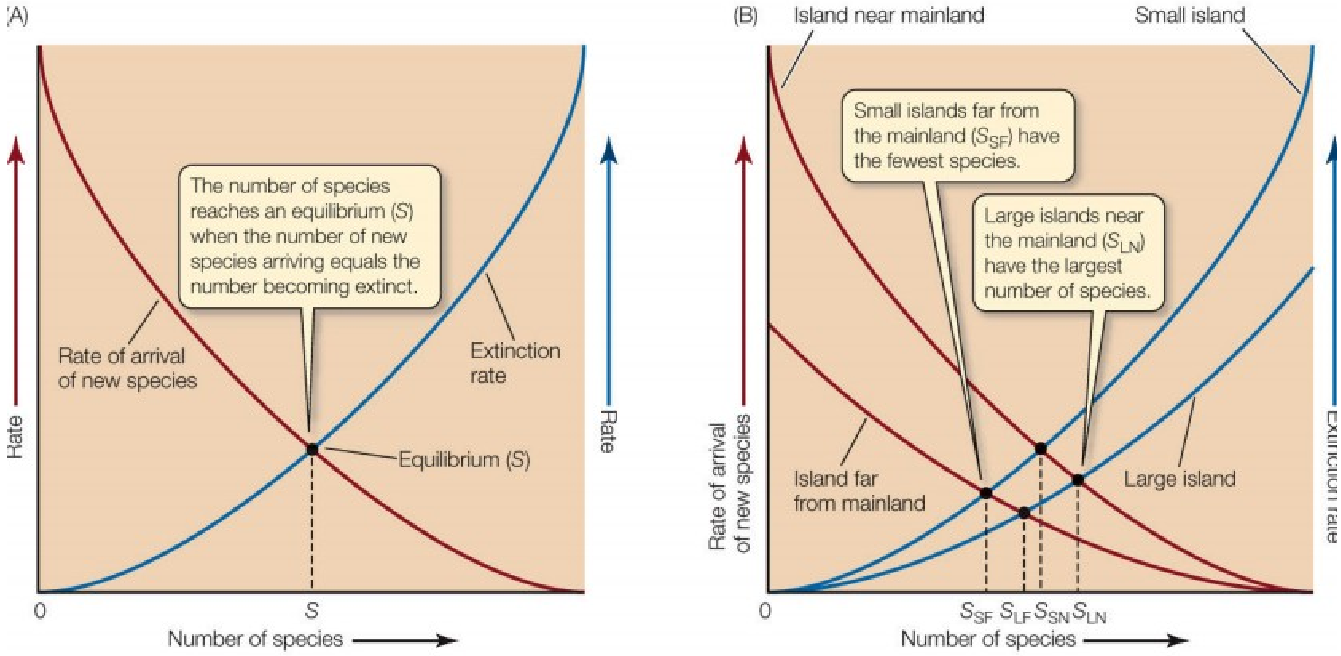
- **Vicariance** - the process by which the geographical range of an individual taxon, or a whole biota, is fragmented by the formation of a physical barrier to inhibit or prevent gene flow or dispersal
- Cannot support species with large populations/territories
- Temperate forests are the only biome expected to increase in area due to planting programs
- **Degradation** – impacts that effect many, but not all, species and that are temporary or possibly reversable
- **Habitat loss** – severe loss, nearly all species affected, takes a very long time to restore the natural system
  - Habitat conversion
    - Light use
    - Degradation – use exceeds production capacity
    - Cultivation
    - Platation
    - Creation of urban areas – increase in amphibians because urban areas tend to have more ponds.

Looking at Habitat Fragmentation

1) Can't support species with large territories
2) Can't support large populations, and smaller populations are at risk of the extinction vortex
3) Influenced by edge effects

- Eventually, new species arriving = the number of species in that area becoming extinct
  - Holds through for islands - **Equilibrium theory of island bio-geography**
  - Fragmented habitats may be considered islands
- Larger fragments = better - can support more species/populations
- With smaller fragments, you lose species diversity.
- Highways cause a lot of habitat fragmentation

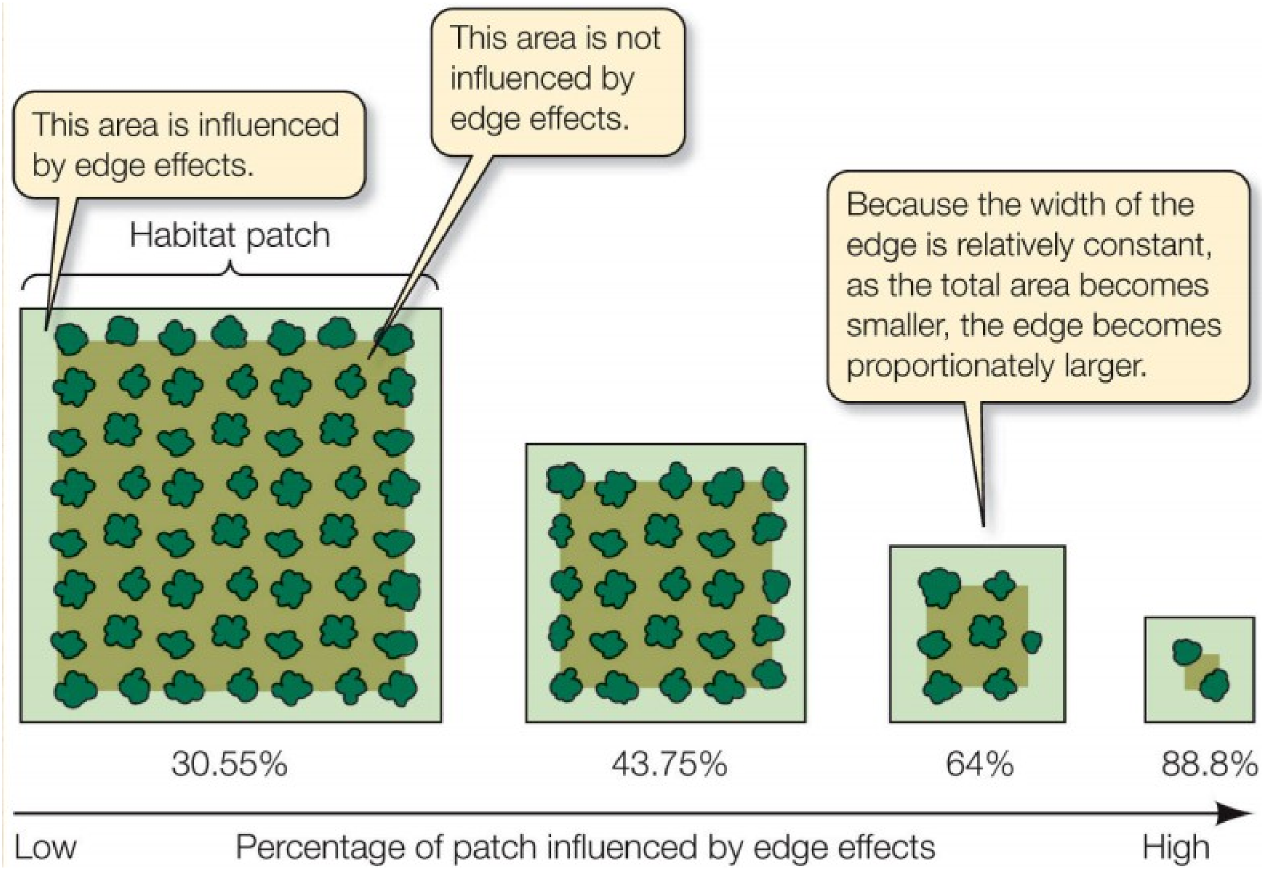
Equilibrium Theory of Island Bio-geography



- As you increase the number of species, you increase competition and predation, which leads to higher extinction rates
- Small islands far from the mainland have lower colonization and higher rates of extinction = fewer species
- This theory holds true for fragmented "habitat islands"
- Negative impacts can be reduced by having connections/corridors

Edge Effects

- Differences in both the abiotic and biotic effects between the edges and the interior
  - Abiotic – Increased sun exposure, increased wind exposure, decreased humidity, increased vulnerability to fire
  - Biotic – More common generalist species, increase in predation, increased interaction with humans
    - Generalists are more common on the edge than specialists - increased fluctuations can be adapted to. More predation (less cover), more interaction with humans
  - Badgers: 53% mortality on the edge (mostly from roadkill), none in interior



- The edge is very much affected by the area - edge effect will be smaller in larger fragments.
  - Also affected by shape – squares and circles have the most interior
- Different edge effects can penetrate different distances into the forest (depending on the type of forest)
  - Tree mortality and invasive beetles = 200m in
  - Disturbance adapted plants = 50m
- There is an obvious relationship between larger parks (Banff/Jasper) with low extinction and some of the smaller parks with more extinction
- Also may depend on when the park was established - newer parks may not have experienced much extinction yet
- Designing preserves to maintain biodiversity must consider what makes the most successful parks work

Processes Which Occur at Forest Edges

- Unexpected consequences for people
  - Smaller fragmented areas, higher incidence of lime-infected ticks; therefore, humans are more likely to contract the disease.
  - In the smaller areas, there are lower numbers of predators, and as a result, the populations of white-footed mice exploded in these areas.

- White-footed mice carry lime disease, and the ticks feed off of the mice. They are reservoirs for the disease.
- In larger territories, there are more predators, and they keep the white-footed mouse populations in check - therefore, less incidence of lime disease.

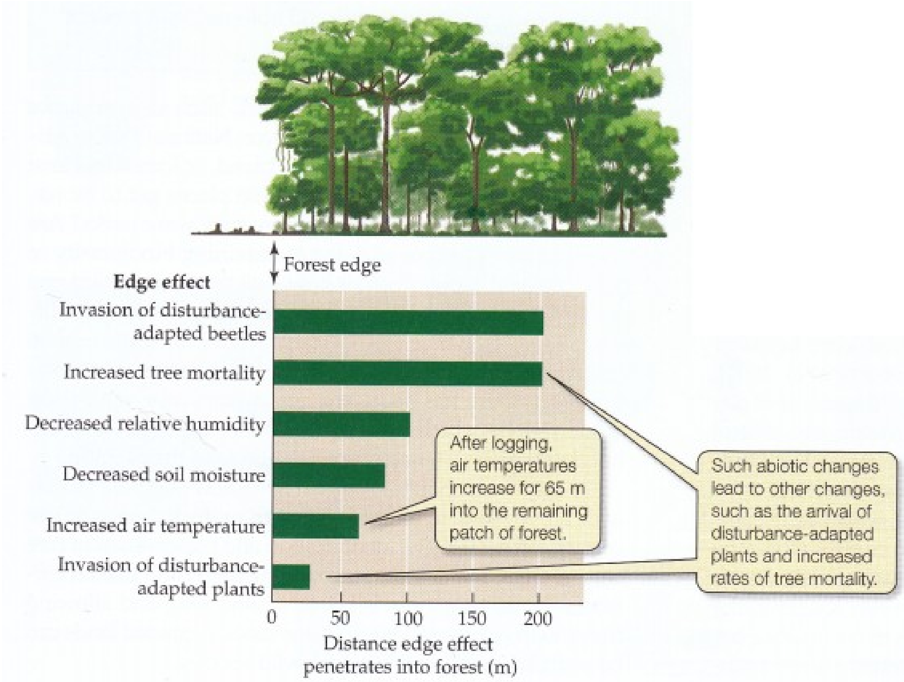


FIGURE 23.15 Edge Effects When an intact forest is first fragmented, abiotic conditions of the environment change near the edge of the patch of forest that remains, giving rise to biotic changes. (After Laurance et al. 2002.)

Deforestation

- Bands of forest are concentrated across northern temperate and tropical regions
- Forests are removed to make room for farmlands and human settlements
  - Logging/lumber, slash and burn, plantations (monoculture, non-native)
  - Northern = logging/lumber
  - Tropics = slash and burn for plantations
- Over 1/2 of the world's forests have been lost.
  - Currently, in 25 countries around the world, there are no forests left.
  - In an additional 29 countries, over 90% of the forests have been lost.
- Ecosystem regulating services are lost with deforestation.
- Demand for land is for crops and increasingly, bio-fuels
- What is a forest? The UN says that plantations are forests, and non-native plants
- In most regions, the net change in forest cover has decreased, particularly in Africa and South America
  - In developing countries, more deforestation occurs because the people are more reliant on clearing forests for farms/food

- There is usually less deforestation in developed countries, possibly because plantations are counted as forests
  - These are better at carbon sequestration
  - Can yield 10x more lumber than forests
- Lots of reforestation in Europe (afforestation)
- China had the most increase in forest cover 2005-2010; however, they import many forest products, causing deforestation in other countries.

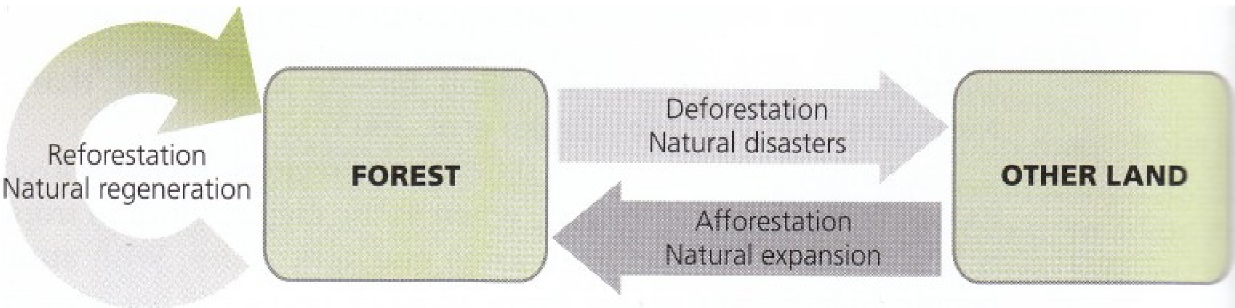


Figure 13.4 A simple model of forest change dynamics. Forested areas include areas that have been temporarily cleared of trees but will either naturally regenerate or be replanted (reforested). *Deforestation* is the long-term conversion of forested lands to other uses, such as agriculture, pasture, or infrastructure. *Afforestation* is the planting of trees on previously nonforested lands. In addition, forests can expand naturally. After FAO (2006).

<u>Lecture 11 – Threats Continued</u>

Ecosystem Services Provided by Forests

- **Air quality services**
  - Air quality regulation is lost with deforestation
  - People in cities often don't consider how important greenery is to air quality.
  - Plants absorb sulfur dioxide through their leaves and remove it from the air.
  - Forests have the potential to absorb more air pollutants/air-born particles (soot) than any other service.
  - They decrease the temperature/provide shade, and this decreases the **VOCs (volatile organic compounds**) released - asphalt as it heats up, for example.
  - It has been estimated that only 6% increase in vegetation cover would cause a 2 degree decrease in temperature and lower smog by 20%
  - Planting trees within the city/rooftops will have an effect! It doesn't need to be a whole forest to have a beneficial effect.
  - Increase air quality = decrease in public health cost

- **Water quality services**
  - Water purification is also lost with deforestation
  - The plants physically trap the sediments/contaminants, and stops them from getting into the drinking water - including wastes
  - Wetlands are also a huge contributor to water purification
    - Reduce water speed to allow for more absorption
    - They also biochemically transform/break down pollutants
  - Fertilizers/Nitrogen - run-off causes algal blooms which reduce the O2 in the waterways and can kill many fish
    - Plants convert N into N gas (de-nitrification) which allows them to go back into the atmosphere where they belong
    - NY decided it was cheaper to restore the wetland than to build a water purification plant
      - If you look at the percent of water in the water shed underneath forests, it would save a lot of money.
  - US - looked at 27 different water suppliers, and correlated it with water cover, and the cost of purifying water increased ~20% with every 10% loss of forest cover
    - MONEY! These stats can be used to argue for the maintenance of forests
  - Sedimentation/siltation
    - The forest helps to trap sediments. When you dam rivers, these sediments are a huge pain - it decreased the dam's ability to hold water (more silt and sedimentation run-off, and the sediment can get stuck in the dam so the dam produces less energy.

- **Erosion regulation**
  - Reduces water flow (main causes of soil erosion are wind and water flow)
  - Root networks hold soil in place. Having a line of trees at the end of a field helps with reducing soil erosion due to wind. - less snow, less wind overall.
  - Reduces precipitation loss by reducing wind, so your fields stay more moist.

- **Pollination Services**
  - Bees pollinating coffee flowers
    - Compared natural pollination vs. hand pollination (very labour intensive).
    - They had the sites different distances away from forest areas.
    - Near and intermediate stations had higher seed mass, higher fruit set, and less malformed seeds.

        - The conclusion was that the coffee plants closer to the forest areas did better than the ones which were farther away.
        - Some coffee plants cannot pollinate themselves, and some can - regardless, pollination caused a significant increase in fruit set.

- **Natural hazard regulation**
    - Trees slow down flow of water into areas - without that cover, you can get flash floods which give very high storm flow volumes.
    - Where mangroves grow there is a significant reduction in wave damage - dissipates wave energy
    - Fewer mudslides - South America, clear-cut areas in BC - nothing to stop the water flow, or hold the dirt in place
    - In NZ, after a cyclone, the incidence of landslides was about 1% where the forest were 5 years old or greater, compared to 30% of where the forests were less than a year old.

- **Climate Regulation**
    - Carbon cycle - trees take in CO_2, and give off O_2
    - Important carbon sinks when they are living – take in Carbon from the atmosphere
        - When they are burned, they are sources of CO_2
    - They help to slow climate warming due to CO_2
    - They have a cooling effect through the shade they produce, and also help with evapo-transpiration
    - They reduce wind - heating costs in the winter in Canada are lower where there are trees to stop the flow of wind.
    - The UN is addressing a lot of these issues
        - MEA - millennium ecosystem adjustment
            - Trying to put a financial value for carbon stored in the forest.
            - Incentives to developing countries to maintain forests, where rich countries to not have forest cover anymore
            - www.un-redd.org
- THESE ARE THE THINGS WE NEED TO KNOW WHILE TRYING TO SELL REGULATION TO THE PUBLIC/GOVERNMENT!

Grasslands, Savanna, and Shrubland Habitats

- Drier, but grow things nicely
- Found in subtropical dry zones

- Used for growing agricultural products
- Maintained by fire, grazing
  - Natural grazing replaced by cows/pasture fields
  - Cattle can do a lot of damage to grasslands
  - South Africa burns grasslands to try to increase productivity of that grasslands - management

Great Plains of North America

- Our grasslands - prairie grasslands have become one of Canada's most endangered places, maybe even moreso than our forests.
  - Alberta has been very heavily converted to agricultural use
  - Very heavily fragmented
  - High biomass herbivores (cattle) which are limited on how much they can move around
  - High impact on grass and on the soil
    - As a result of this conversion, lots of drainage of the aquifers for irrigation - decreased flow of the streams.
    - Water management is a huge issue out West.
- So many species in this biome (buffalo/bison) are very threatened
  - Bison were the dominant herbivore in the plains, but were driven to near-extinction (600 individuals). With loss of habitat, even though their numbers have recovered slightly, there is no place for them to actually go.
  - Blackfoot ferrets, prairie dogs, burrowing owls, horned lizard, kangaroo rat, sage grouse, swift fox – endangered
  - Prairie dogs were poisoned, loss of other species who predate/use the holes of the prairie dogs (BFF, burrowing owls) also suffered - BFF captive breeding has been successful, but re-introduction has been an issue because the BFF need prairie dogs for their nests.
- In South Africa there is no wildlife outside of reserves; everything else is heavily managed for agriculture.

Desertification

- Loss of fertile land through human overuse into desert
  - Drought/inappropriate agriculture over long periods of human occupation
    - Roman Empire rose in a moist climate, part of the collapse was a result of climate change (less agriculture)
- Forest/grassland/savannah - when we convert it, it can turn into a desert.
  - Some places are more vulnerable than others

- Sahara expanding up to 48 km/year - bad for humans and species diversity.

Lecture 12 – Pollution

Threats to Biodiversity Continued: Pollution

- Disasters: Exxon Valdez (1989)
  - Ran aground, and 11 million gallons of oil was leaked off the coast of Alaska
  - Killed river otters, sea otters, harbour seals, bald eagles, orcas, salmon and herring.
    - When animals clean themselves, they ingest the oil.
  - Since the spill, most species (other than herring) have recovered
    - 3 years after spill (length of time for herring to reach maturity) the population crashed – no evidence confirms method of impact
  - Stunted growth in salmon
  - Resident Orca pods lost members, and many disappeared entirely
  - Oil is still present beneath the rocks on the shoreline
    - Only degrades about 4%/year – cleanup not entirely effective
  - Now stricter regulations on oil transport
    - The Deep Water Horizon (2010) in the Gulf of Mexico caused a similar disaster. It reached the amount of oil spilled by Exxon Valdez in 50 days; 200 thousand gallons per day.
    - We can only clean up about 15% of the oil – most sinks to the bottom of the ocean or is ingested by animals
    - It is very difficult to get accurate numbers when monitoring an ocean population

Plastic Pollution

- North Pacific Gyre – due to ocean currents, garbage concentrates in this area
- Everything is made out of plastic!
  - Only 7% is recycled in the US
  - Currents bring together land-based trash from around the world
  - Bits of plastic outweigh zooplankton 6:1
  - Most debris is a few feet below the surface
  - The amount of garbage is 2x the size of Texas
  - Animals ingest plastics
  - Plastics leach chemicals

    - "Ghost nets" abandoned by fishermen trap fish
    - How do they propose to make bioplastic?
        - Produce bio-gas from landfills - feed bacteria which produce plastics inside of them
        - This plastic is non-toxic and can be combined with fibres
        - Everyone can make little changes to reduce their use of plastic

Persistent Organic Pollutants (POPs)

- Persistent, Bioaccumulative and Toxic (PBT)
- Toxic Organic Micropollutants (TOMP)
- Remain in the environment for a long time
    - Are lipophilics (dissolve in fat)
        - Stored in the fats of organisms, not easily excreted – as opposed to water-soluble vitamins that are excreted in the urine
        - Organic (c-based) – resistant to environmental degradation
- Originate from agriculture and industrial activities, such as burning trash
- Common in plastics (BPA)
- DDT
    - Used to control mosquitoes and other insects (1930s)
    - 1962 – Rachel Carson, Silent Spring
        - Brought hundreds of research studies to the public eye
        - Many industries attack her conclusions
        - Birth of the modern environmental movement
        - Now DDT is banned in most parts of the world
            - Still used and produced in India
            - It can persist and travel

Biomagnification/Bioaccumulation

- Biomagnification – increase of toxin in animals that feed higher on the food chain
    - The concentration is higher than in lower animals, because they eat a lot of lower animals
- Bioaccumulation – organism absorbs toxin at a rate greater than the rate at which it is expelled, so the toxin accumulated over the lifespan of the organism
- Top bird predators – Bioaccumulation of DDT results in thin eggshells, so the adults would

crush their eggs when they nest – caused a population crash

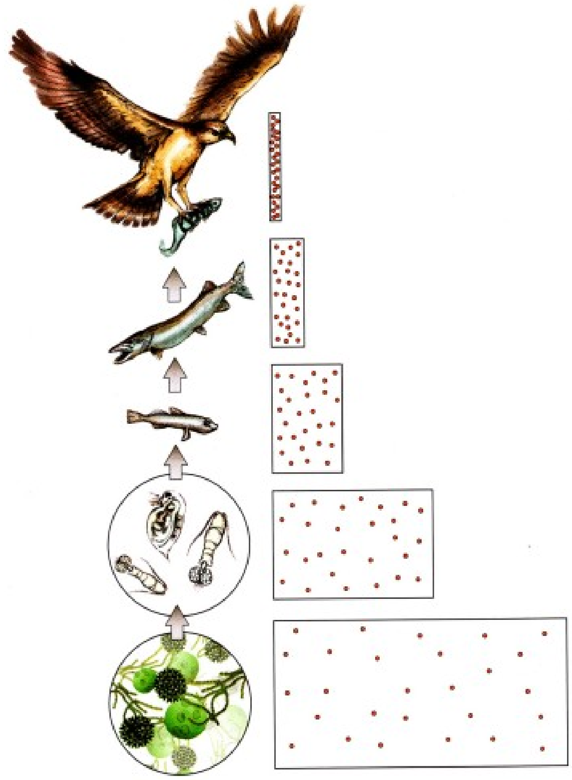
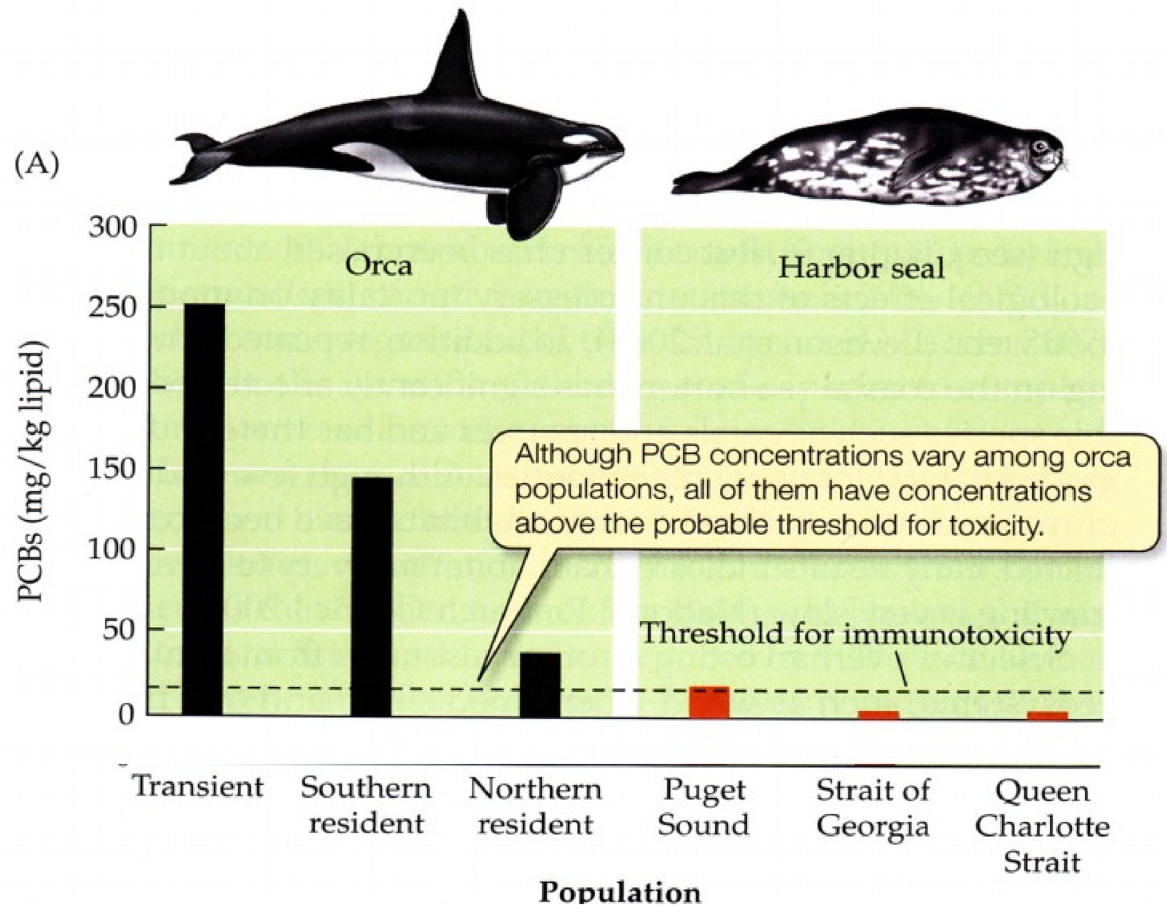


Figure 14.6 Biomagnification of DDE, a breakdown product of DDT. Because DDE is a highly stable compound, not easily broken down or excreted by plants or animals, its concentration is greater in organisms that feed higher on the food chain. The diminishing size of the boxes as trophic level increases illustrates the declining biomass of organisms from one trophic level to the next, and the concentration of dots reflects the concentration of DDE per unit biomass.

Polychlorinated Biphenyls (PCBs)

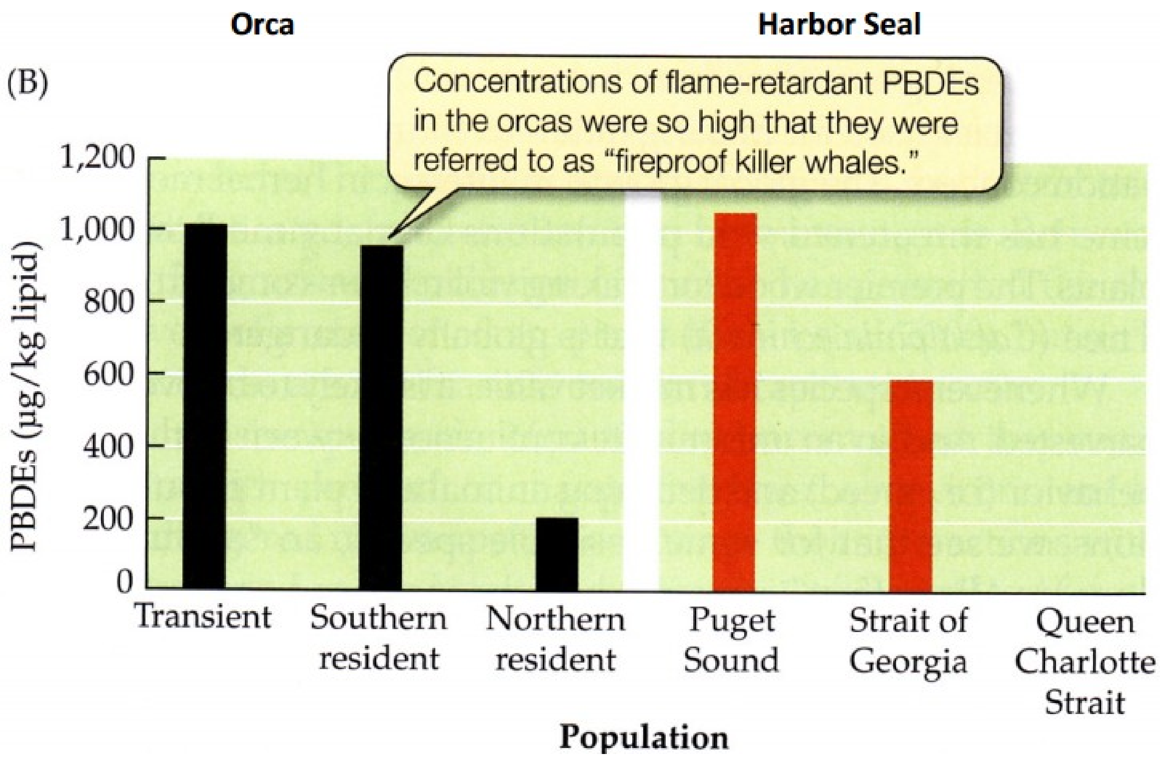
- In plastics, oils
- Causes reproductive problems, cancer
- PCBs concentrated in the Arctic, because they can travel through atmosphere
  - Native populations eat many large mammals that have high PCB
- Plastic pieces in the ocean containing PCBs are eaten by filter feeders
- Animals (transient orcas) eating higher up in the food chain have higher levels of PCB (resident orcas eat mainly fish)



- Fish from the Great Lakes have high levels of PCB

Endocrine Disrupting Chemicals

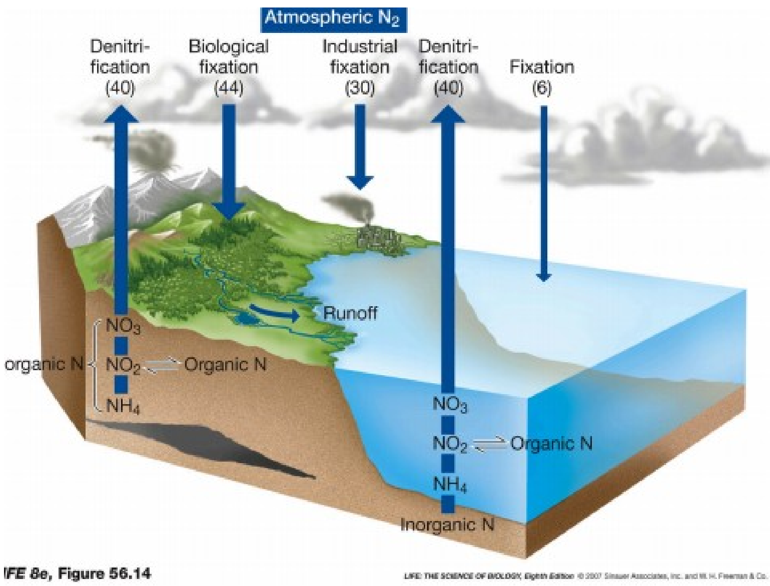
- **PBDE** – a flame retardant
- Orcas are a long-lived predator with lots of blubber
    - Fat from the blubber produces breast milk (the calf gets all accumulated toxins from the mother)

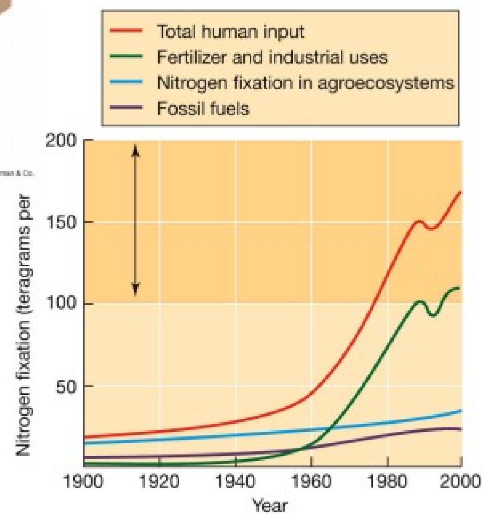


- **Bisphenol A (BPA)**
    - Endocrine disruptor (environmental estrogen)
    - Found in plastics
    - Reproductive impairment (intersex fish) downstream of the waste water treatment plant
    - Canada has banned BPA in baby bottle plastic (potential to leach into food when bottle is heated up)

Nitrogen

- 78% of the atmosphere (most organisms cannot use it directly)
- Nitrogen fixers make N available to plants, and denitrifiers return it back to the atmosphere
- Usually Nitrogen is limiting in ecosystems
    - Fertilizers contain Nitrogen
- Human addition of Nitrogen to ecosystems is far above the amount fixed naturally
    - Terrestrial systems – plant species are adapted to low N levels, and when we fertilize an area, pasture plants take over and rare species are lost.
- Excess Nitrogen runs off into groundwater and streams
    - Addition of nutrients to water causes **eutrophication**





Eutrophication

- Anoxia – low oxygen levels – results when eutrophication occurs and algal populations increase dramatically. Their decomposition uses up all available oxygen.
- Dead zones
    - Algae blooms and then dies – as they decompose, they use of oxygen and create dead zones.
    - Mississippi Delta – large seasonal dead zone in the Gulf of Mexico.
    - The number of dead zones has doubled every decade
    - Clustered near more highly-developed nations

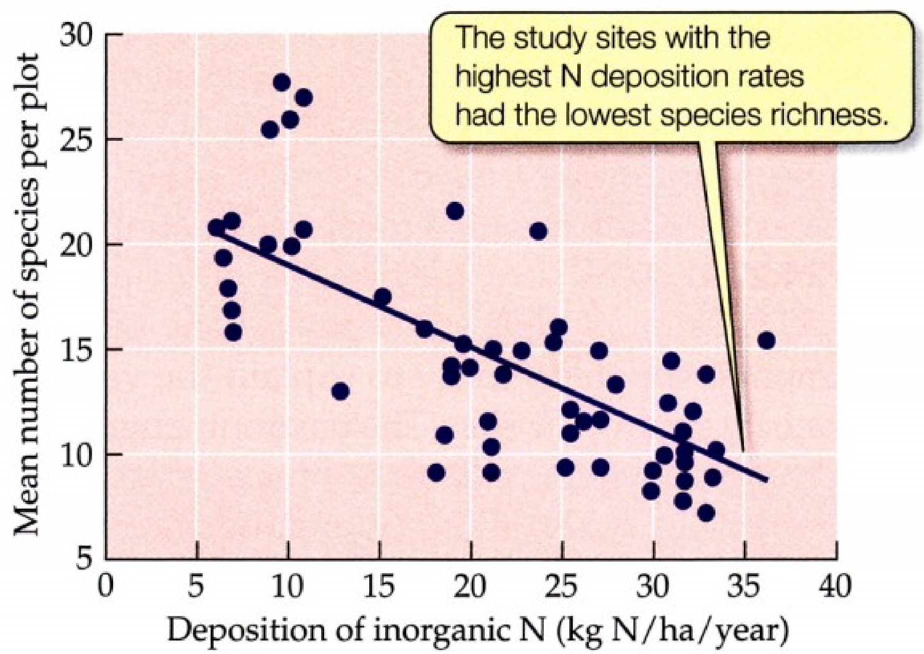


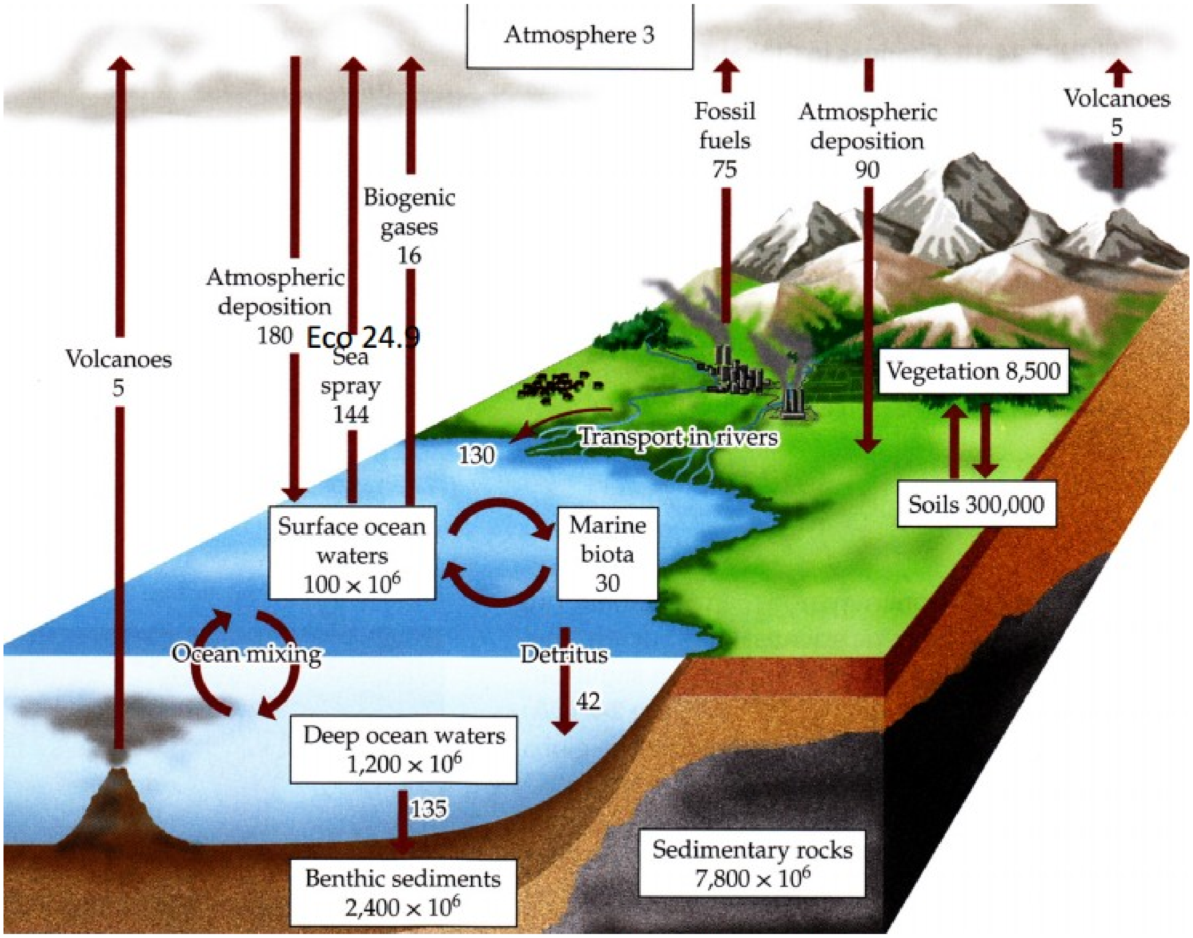
FIGURE 24.22 Nitrogen Deposition Lowers Species Diversity (A) Inorganic N deposition in the United Kingdom. Dots on the map indicate the study sites where plant species richness in grassland ecosystems was measured. (B) Correlation between rates of inorganic N deposition and plant species richness. (After Stevens et al. 2004.)

Sulphur

- Sulphur is not often limiting – most is found in rocks, and is slowly released at they weather
- Burning fossil fuels (coal) releases sulphur
- 4x more sulphur is released since the industrial revolution

Acid Rain

- Sulphur combines with water in the atmosphere to form acid rain
- Most species have a small pH range in which they can live.
- Highly acidic lakes support fewer fish species – lower species biodiversity



Lecture 13 – Over-exploitation

Over exploitation

- 2nd most important threat to birds, mammals, and plants

-primary threat is habitat loss/fragmentation

-Freshwater overexploitation comes after invasive species and habitat loss, but marine systems follow the terrestrial theme.

Population growth is assumed to the density dependant with increased per capita rate of mortality and decreased per capita rate of reproduction at higher densities because of increased consumption for limited resources and increased disease loss.

Maximum sustainable yield

- Largest possible harvest that can be indefinitely supported by the population (stock).

- Logarithmic increase into the population number until equilibrium (reproduction = mortality)

- We want to harvest the population when it is growing at the maximum rate. If you harvest above that, there is a decrease in the overall yield.

Tragedy of the commons

The depletion of a shared resource by individuals acting independently according to one's self-interest, despite understanding that depleting the common resource is contrary to the group's long-term best interests

Fishing - from 1950s onwards, new technologies were developed for fishing - before, technology limited them, and their methods allowed them to target specific species.

1) new technologies allowed fishing more area and depth (so increase source to replenish stock)

2) Trawlers had enormous bycatch, including prey species.

This caused A HUGE drop in population in cod. Fishing was no longer economically feasible. Cod stocks have not recovered.

Between 20-30% of fish stocks are currently overharvested.

Bycatch - economically unimportant creatures/unwanted creatures caught when trying to catch the stock animal - noncommercial

How much bycatch depends on the methods used - trawls, long lines, and method traps

Each year there are millions of tonnes of turtles, sea birds, mammals caught when fishing

When the bycatch contains prey species for the species you are looking for, you are really shooting yourself in the foot.

Big issue in bycatch is sea turtles - very endangedm, often caught uop in shrimp trawling nets. Their populations were crashing - they thought it might be their egg lifestyle/beach destruction, but modeling revealed that infant mortality did not affect the population much - the adults were being caught. They worked with the fishing industry to create turtle-excluding nets (with an escape hatch, while maintaining fish caught)

The Bushmeat Crisis

Overexploitation in Africa, Madagascar,

Lemurs - hunted by the indiginous people for food, and for fur, exotic pet trade,

1) Increased access to guns

2) increased road access to the bush

Cultural demand for creatures

- not for clothing, not for food.

-sequentiual depletion -ivory in hippo and elephant

- poaching for ivory is a huge issue now that they are protected

- hippos were gone after after elephants were protected

Lecture 14 - Overexploitation, Invasive species

Conservation biology March 5

Overexploitation continued

Required reading: Grooms Case study 8.2

Increased access, increased guns

- bushmeat helps to increase protein intake for poor farmers
- increase economic status will decrease need for bushmeat? - many will still prefer to eat bushmeat (tradition)

What life history characteristics is key to sustainable trade in wildlife for bushmeat?

Bushmeat crisis task force - BCTF - describe?

What are the four areas of engagement that the BCTF has prioritized?

What are the three leading success indicators directly related to bushmeat that are employed by CBFP for landscape management efforts

Describe the COMACO project, and why is it innovative?

OVEREXPLOITATION - CULTURAL DEMAND

- Certain species are more succepatable to overexploitation because of their reproductive status
- sustainable harvest - things more towards the r selection are easier to farm sustainably

CULTURAL DEMAND

- Elephants - cultural demand (ivory, collection kills the elephant) but K selection - slow to reproduce, poaching damaged extremely. Ecosystem engineers (pull down trees, make water holes)
- 35% population decline in the last five years in the COngo reserve -f rules are not enforced, it means nothing
- rhinos - to try and save the species , to legalize the sale of rhino horn - alternative plant sources for aphrodisiacs suggested, but have failed to curb demand - tradition. The suggestion is to "farm" rhinos, but breeding rhinos in captivity, especially thiose which are long lived and have very few young, is very difficult. Can harvest the rhino horn without killing the rhino. Rhino horn is currently more than the worth of gold. Horn grows back at 5-6cm/year. How much is the horn worth vs housing the rhino in captivity
- Saiga antelope - Sequential depletion - Mongolia/China. The numbers were more than 2 million, very large herds - reproductive biologiy is like sheep (females have 2 calves per year), high reproductive potential. They are herbivores, and eat several species of plants which are poisonous to other animals - they lower the poisonous plants level. Only the males have horns. Populations have declined 95% in 15

years, the fastest decline seen. The hunting for the males is to blame. All wildlife management after the collapse of the soviet union were on their own. The sequential depletion is because the male saiga horn has been suggested as a replacement in Chinese medicine for rhino horn - almost dirven to the point of extinction. The saiga was suggested as an alternative by the WWF. Although they are better suited than rhinos to sustain a harvest, the harvest pressure is too great for the them.

Hippo - ivory source as well, their place in the ecosystem is very important - hippo dung is an important food source for many invertebrates and fish, which are also supported by the invertebrates. In areas where hippos are hunted out, there are no fish - the people who live around the lakes where there are no fish are now starving.

- American Alligator - once on the verge of critical extinction, has made a remarkable recovery because of extensive research into their biology as well as strict conservation efforts. Hunting for their skin/habitat loss initially decimated their population. They became protected, and were closely monotored. in 1997 they were removed from the endangered species list. it is now farmed commercially, and that has reduced the amount of alligators killed in the wild.

Why would this work for alligators and not for rhinos?

- Governmental stability, more enforcing of the protection

- less desired/expensive than rhinos

- reproductive physiology is different - alligators are r influenced, and have many young.

EXTINCTION VORTEX WILL BE ON THE FINAL EXAM IN MORE DETAIL - EXPLAIN DETAILS

Final exam is cumulative, will be an emphasis on the second half, will be the same format as the midterm - exams may have case studies/ask to give examples

Allee effect - decline in the survival or reproduction of individuals that predictably results from reduction in population size

- can be seen in sessile organisms (too far away from each other at low densities for sperm to reach the female/eggs)

- American Ginseng - at risk (taken for its medicinal properties) - looked at densities in a plot - at low densities, lower number of fruits per plant. Pollinators had difficulty finding smaller patches, and would sometimes avoid smaller patches because it would take them more effort for less reward.

- whales - some that are normally solitary can't find mates, and do no have offspring.

- Vancouver island marmots - live on alpine meadows, and were so scattered that they could not find mates

- "how low can we go before we experience reproductive decline?" - important to know, different species are affected by the allee affect at different strengths

If any aspect of reproduction or survival of a species is enhanced by increased proximity to conspecifics then they are subject to the allee effect at lower density

African wild dog - historically very abundant, predators (prey on gazelle, medium prey) - were considered threats to wildstock - governement sponsored hunting initiatives. The sponsorship stopped, but the numbers have not recovered, and for a while they couldn't figure out why. They typically hunt in very large packs (more than wolves) and they cooperatively hunt to take down larger prey like wildebeasts (maximize return for hunt - 12-15 individuals, also help to protect kill from scavengers). A pack of 5 or less is subject to lowered reproductive success. Survival is enhanced by higher densities. Smaller packs are much more willing to adopt pups than larger packs. They are planning on taking pups from larger packs and giving them to smaller packs to help recover the populations.

Allee effect is important when considering sustainable farming, as well as conservation/repopulation efforts.

GRAPHS

Below critical population density, growth rate is negative.

Species with a weak allee effect do not have critical population densities

Allee effect is due to biology, but the anthropogenic allee effect is caused by humans.

- As an animal becomes more rare, value for humans increases.

- red line is price, blue line is cost/unit to harvest

- at low population numbers, they are pretty scattered - more effort to find the species to harvest it.

- With more population, it costs less to actually find/harvest it.

- if the prices does not change relative to the price to harvest, the lines cross and that is where harvest is sustainable.

- Anthropogenic effect - prices raise as species becomes more rare

- White abilone - off of the american coast, considered a delicacy - used to be very common in the early 70s (1000-5000/acre) - price remained constant, until densities fell - price spiraled up. In the 90s, the density was 1/acre, and was listed under the endangered species act, and prices are ridiculously high. Both subject to the anthopogenic allee effect and the regular allee effect (need to be close to the female to spawn, broadcast spawners)

- rhinos

Lecture 15 - Invasive species

Introduced vs. Invasive

- Introduced species are not necessarily invasive - invasive has a detrimental effect on the native wildlife

Humans are the most invasive species

Because humans have invaded every corner of the planet, we have brought invasive species with us.

Not all introduced species will be considered invasive (detrimental)

Which ecosystems are more suscepatable to invasion

How are animals inroducd - by humans, ntentionally or unintentonially

CONSERVATION IMPLICATIONS OF INTRODUCED SPECIES

wild plains of north america - 11% are non-native

in hawaii - 35% are non native

San Francisco Bay

- in 1950, the est. rate of successful new introductions was approx 1/year. in ten years, it had increased to 4/year.

Humans are the main cause of introduced species

- range/expansion is normal for species (allopatric)
- the rate of human caused introduction exceeds that number exponentially
- sometimes it is intentional, other times non-intentional. (Stowaways, creatures in ballast in ship)

Good news: it follows the tens rules

10% of creatures escape, and only 10% of those manage to establish a successful population, and only 1% of that becomes invasive.

If you increase the number of introductions, you will incrase the likelihood of successful intorduction, and increases the chance of a creature becoming a successful invader.

Increase frequency of introductions and number of creatures introduced increases the chance of an invasive species

Example - starlings

Propagule Pressure - the frequency of introductions and quantity of organism introduced to a site

Higher propagule pressure increases the likelihood that an introduced species will establish a self-sustaining population

Population and community impacts

- Introduced species as they exist are neither beneficial nor detrimental (honeybee good, introduced species outcompeting one which we're trying to re-establish bad)
- introduced predators
- Brown tree snake in Guam

- hitchchiked on a war ship in WW2

- ate native bird species to extinction

outcompeted the one native snake species

-reduced total biodiversity on the island

Giant African Snail - introduced into Hawaii as a garden ornamental

Did very well in Hawaii, but started to be considered a pest.

People introduced 15 non-native carnivorous snails to eradicate the African Land snail (3 of which established themselves)

None of them had a significant effect on the African land snail, but exterminated greater than 56 land species in the South Pacific.

Illustrates the danger of using biological controls!

Cats - domestic cats

- walking weapons, evolved to kill and love it.

Introductions of cats to islands is worse - 70% has detrimental, versus 30% on land. Islands often don't have many native predators

-cats either take over or share the predation in an area

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<u>Illustrates the danger of using biological controls!</u>

Introduced Competitors

- Impacts of competition by invasive species are often trickier to observe and measure than those of predation; however, a number of conspicuous invaders appear to have caused large ecological changes through direct and indirect effects of competition.
- Zebra Mussels
  - From Russia – now invasive throughout the world
  - They disrupt the ecosystems by **monotypic colonization,** and damage harbors and

waterways, ships and boats, and water treatment and power plants.

- Eg zebra mussels from Asia on unionid mussels endemic to eastern NA. It differes from the unionids in two important ways – its larvae are planktonic and disperse freely while unionid plankton require a fish host for dispersal. Also, zebra mussels has byssal threads with which it attaches to hard substrates such as docks, boat hulls and other bivalve shells. It settles at high densities onto unionid shells, reducing their ability to filter water and respire, feed or excrete wastes. They cause more unionid extinctions than habitat loss.

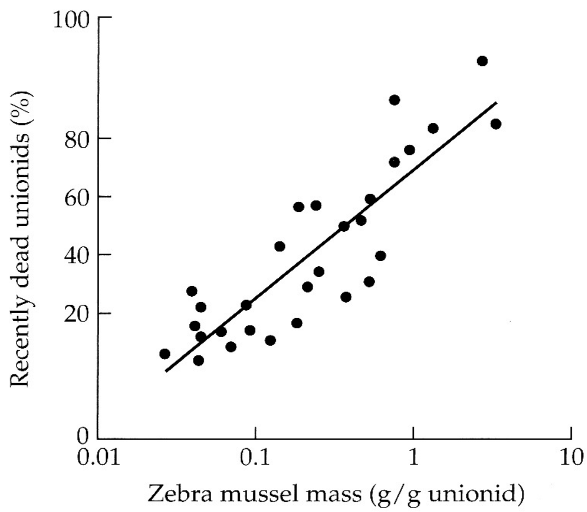

Figure 9.4 Percent of native unionid mussels recently dead as a function of the relative wet weight of introduced European zebra mussels (*Dreissena polymorpha*) attached to their shells. Note log scales. (Modified from Ricciardi 2003.)

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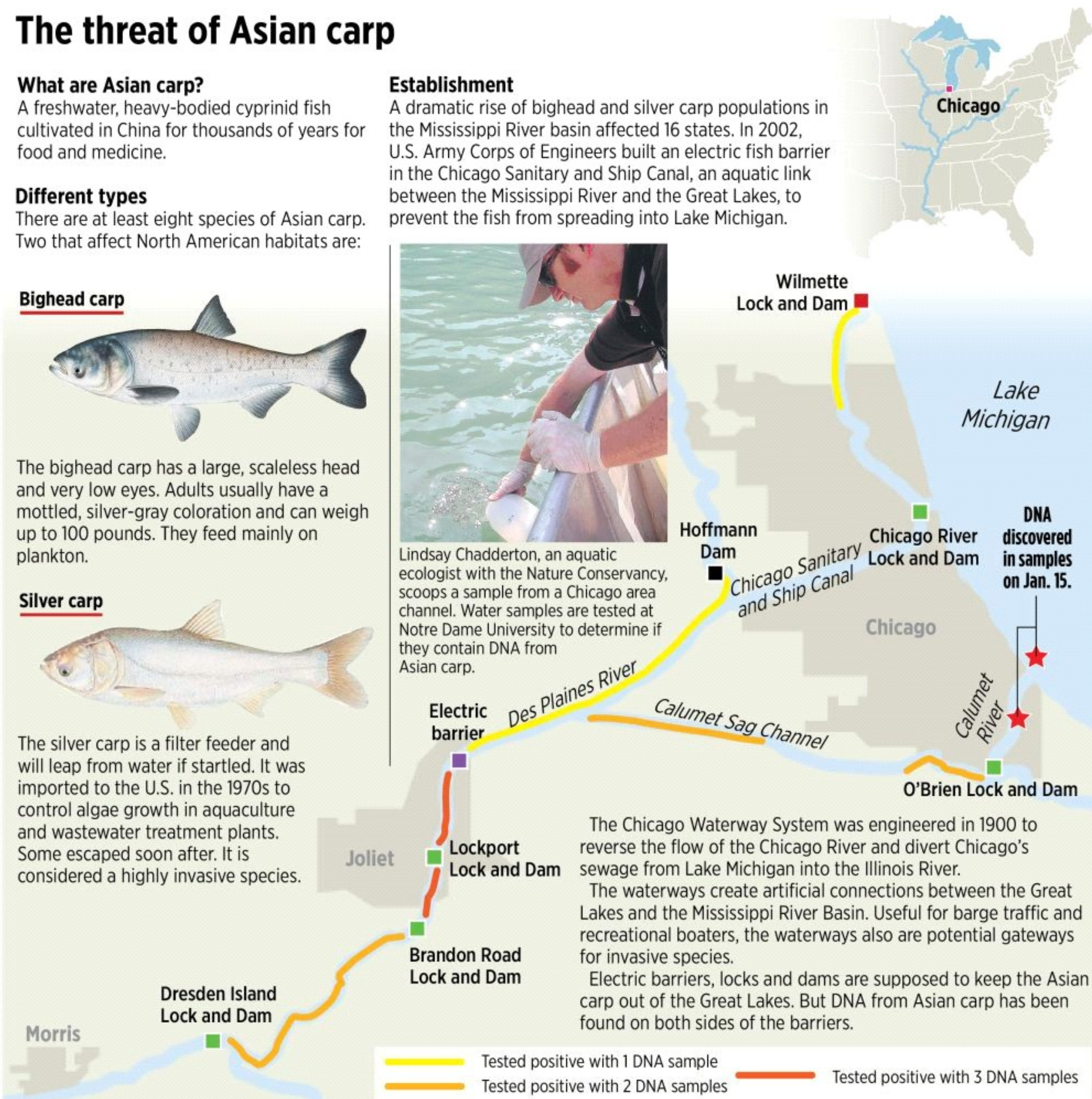
water clarity has increased from 6 inches to up to three feet in some areas.[5] This improved water clarity allows sunlight to penetrated deeper where macrophyte bacteria can now grow. This bacteria when decaying, can wash up on shorelines fouling beaches and causing water quality problems
The catch of yellow perch increased 5 fold after the introduction of zebra mussels into Lake St. Clair
The vast majority of the organisms that are natural enemies in Europe are not present in North America. Ecologically similar species do exist but it is unlikely that these species are able to eliminate those mussels already established and will have a limited role in their control. [12]
Crayfish could have a significant impact on the densities of 1 to 5 mm long zebra mussels. An adult crayfish consumes an average of nearly 105 zebra mussels every day, or about 6000 mussels in a season. Predation rates are significantly reduced at cooler water temperatures. It seems that fish do not limit the densities of zebra mussels in European lakes. Smallmouth bass are a predator in the zebra mussels' adopted North American Great Lakes habitatZebra mussels are believed to be the source of deadly avian botulism poisoning that has killed tens of thousands of birds in the Great Lakes since the late 1990s.[28] Because they are so efficient at filtering water, they tend to accumulate pollutants and toxins. For this reason, although they are edible, most experts recommend against consuming zebra mussels.[29]
They are also responsible for the near extinction of many species in the Great Lake system by out-competing native species for food and by growing on top of and suffocating the native clams and mussels.[30]

However, zebra mussels and other non-native species are credited with the increased population and size of smallmouth bass in Lake Erie[31] and yellow perch in Lake St. Clair.[32] They cleanse the waters of inland lakes, resulting in increased sunlight penetration and growth of native algae at greater depths. This cleansing also increases water visibility and filters out pollutants. Each quagga and zebra mussel filters about 1 US quart (0.95 l) of water a day when confined to small tanks.[33] In lakes, their filtering effects are usually spatially restricted (near the lake bottom) due to non-homogeneous water column mixing.

- Asian Carp



- The **common carp** (*Cyprinus carpio*) is a widespread freshwater fish of eutrophic waters in lakes and large rivers in Europe and Asia.[2][3] The wild populations are considered vulnerable to extinction, but the species has also been domesticated and introduced into environments worldwide, and is often considered an invasive species.[2] List of the world's 100 worst invasive species.

C. carpio is the third most frequently introduced species world-wide (Welcomme 1992, in Saikia &

Das 2009). On every continent where it has been introduced it has reduced water quality and degraded aquatic habitats = ecosystem engineers
Due to their fecundity and their feeding habit of grubbing through bottom sediments for food, they are notorious for altering their environments. In feeding, they may destroy, uproot, disturb and eat submerged vegetation, causing serious damage to native duck, such as canvasbacks, and fish populations.[20] Similar to the grass carp, the vegetation they consume is not completely digested, and rots after excretion, raising the nutritional level of the water and causing exsessive algae growth. They destroy nests of other fish and eat their eggs, reducing their numbers significantly.
Cyprinus carpio is the number one fish of aquaculture.
Asian carp aren't direct predators, but they eat plankton, which knocks out the bottom layers of the food chain. If they were to successfully establish themselves in the Great Lakes and start breeding, they could utterly disrupt the existing ecosystem, potentially starving out the trout and other native fish that make the Great Lakes a tourism hot spot
Scientists and policymakers are concerned that the invasion of Asian carp in the Great Lakes could wreak havoc on the region's fishing industry, which is worth $7 billion.

-

Morphological and Behavioural Impacts of Invasive Species

Define introduced species

Introduced species are not neccesarily invasive - invasive has a detrimental effect on the native wildlife

Humans are the most invasive species

Because humans have invaded every corner of the planet, we have brought invasive species with us.

Not all introduced species will be considered invasive (detrimental)

Which ecosystems are more suscepatable to invasion

How are animals inroducd - by humans, ntentionally or unintentonially

CONSERVATION IMPLICATIONS OF INTRODUCED SPECIES

wild plains of north america - 11% are non-native

in hawaii - 35% are non native

San Francisco Bay

- in 1950, the est. rate of successful new introductions was approx 1/year. in ten years, it had increased to 4/year.

Humans are the main cause of introduced species

- range/expansion is normal for species (allopatric)

- the rate of human caused introduction exceeds that number exponentially

- sometimes it is intentional, other times non-intentional. (Stowaways, creatures in ballast in ship)

Good news: it follows the tens rules

10% of creatures escape, and only 10% of those manage to establish a successful population, and only 1% of that becomes invasive.

If you increase the number of introductions, you will incrase the likelihood of successful intorduction, and increases the chance of a creature becoming a successful invader.

Increase frequency of introductions and number of creatures introduced increases the chance of an invasive species

Example - starlings

Propagule Pressure - the frequency of introductions and quantity of organism introduced to a site

Higher propagule pressure increases the likelihood that an introduced species will establish a self-sustaining population

Population and community impacts

- Introduced species as they exist are neither beneficial nor detrimental (honeybee good, introduced species outcompeting one which we're trying to re-establish bad)

- introduced predators

- Brown tree snake in Guam

- hitchchiked on a war ship in WW2

- ate native bird species to extinction

outcompeted the one native snake species

-reduced total biodiversity on the island

Giant African Snail - introduced into Hawaii as a garden ornamental

Did very well in Hawaii, but started to be considered a pest.

People introduced 15 non-native carnivorous snails to eradicate the African Land snail (3 of which established themselves)

None of them had a significant effect on the African land snail, but exterminated greater than 56 land species in the South Pacific.

Illustrates the danger of using biological controls!

Cats - domestic cats

- walking weapons, evolved to kill and love it.

Introductions of cats to islands is worse - 70% has detrimental, versus 30% on land. Islands often don't have many native predators

-cats either take over or share the predation in an area

Giant African Snail - introduced into Hawaii as a garden ornamental

Did very well in Hawaii, but started to be considered a pest.

People introduced 15 non-native carnivorous snails to eradicate the African Land snail (3 of which established themselves)

None of them had a significant effect on the African land snail, but exterminated greater than 56 land species in the South Pacific.

Illustrates the danger of using biological controls!

INVASIVE SPECIES SPECIALIST GROUP

-Introduced competitors

- Zebra mussels - native to Russia, invasive throughout the world. They distrupt the ecosystems by monotypic colonization - they outcompete the native mussels and are the only species present.

-They prey on unionid mussels - they attach to the shells as a substrate, and they suffocate the native ones.

Why are zebra mussels so successful?

larvae can swim around on their own, as opposed to the unionid mussels which need to be spread by fish

when they get in high densities, water clarity increased -can cause problems, decrease quality

when they decay they wash up onto the beaches and affect water

We don't have an equivalent of their natural predators

believed to be the source for avian botulism

buildup of pollutants in the mussels make them inedible for human consumption

Asian carp - 3rd nmost introduced species in the world, and in every continent where it has been introduced it has lowered water quality and devastated local environments - it is an ecosystem engineer

They grub at the bottom of the sediment for food, and uproot vegetation (damages fish and duck populations)

What they consume, they are bad at digesting (plant matter) they defacate a lot out, and it rots after excretion, which raises the nutritional content of the water which increases the chance of algal blooms and destroys the nests of other fish as well as predates on the eggs

They eat plankton as well as undrwater veg, and that knocks out the bottom layer of the food chain. It has been suggested that if they get into the great lakes, they could destroy the ecosystems present in the great lakes - great lakes fishing indisctry = 7 bilklion dollars

does very well in eutrophic environments, and with reduced oxygen

Lecture 16

Lecture 17

Lecture 18

CITES – Convention on the International Trade In Endangered Species

- Our government voted against listed polar bears under this act – they said that the impact was mostly climate change and not hunting. This was influenced by the Northern Contituents who use the polar bear for food etc.
- The current hunting of polars bears is not in itelf a thret to polar bear population, but it does add to the cumulative effect (pollution climate change hunting etc)
- Created when the US saw some issues with the ESA

International Conservation Agreements

- Is a treaty – legally binding
- UN is responsible for enforcement
- Global environmental facility which provides funding for developing countries to follow this agreement
- US signed, but did not ratify it.
- Canada signed and ratified – SARA created

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Lecture 19 – Protected Areas

How Bad Is It?

- It is difficult to get this information, but essential for the creation of law of legislature
- What will have the greatest effect for your money?
  - Preventing poaching
  - Recovering habitat
  - Captive breeding

1) The number of individuals in the current population
   - How many are left? How many were there historically?
2) The trend in population size
   - If the population is dropping, then what will be needed for recovery of this species
3) Estimate of the immediate risk of extinction (the population viability)
   - What threat is most driving them to extinction, and how can we mitigate that?
   - 1000 individuals might be alright for one species, and not for another

Estimating Population Size

- In the US, fewer than 1/4 of recovery plans have current population data, and only 4% have an estimate of trend.
- Census
  - Direct count – will only work on organisms in a limited space that do not move around (not frequently done)
  - All life stages must be readily available
- Sampling and Extrapolation
  - Sample the number of animals in one area, and extrapolate to the larger area
  - Usually done per unit space/sampling effort (fisheries usually go by sampling effort – how many days/times associated with number of fish)
  - In theory, sampling sites are randomly selected, but this is not always true.
    - "The sample was biased because the plants were growing in a thorn bush and I didn't want to stick my hand in too far" #overlyhonestmethods

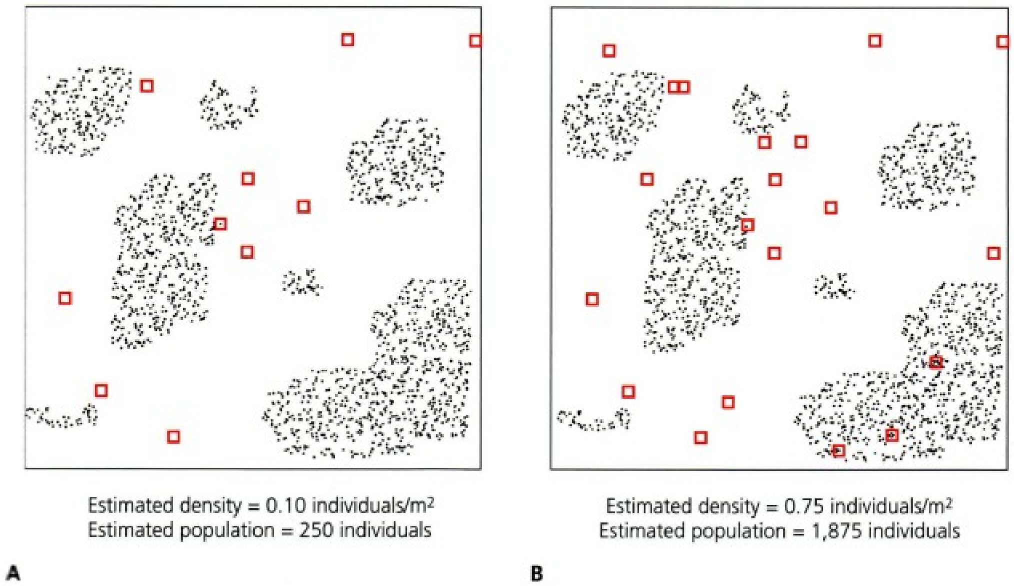


Figure 8.2 Sampling effort and the accuracy of population estimates. Sampling a population of 1,957 patchily distributed plants using **(A)** 10 randomly placed quadrats versus **(B)** 20 randomly placed quadrats.

- Count the number of individuals in each sample, then extrapolate. While only going with 10 sampling sites, the number is much different/more inaccurate view then when we have a greater number (20)
- Increasing sampling sites increases accuracy, but also cost.
- A trade-off in term of bias (more accessible, less expensive to sample, you may sample more of them)

Sampling

- Direct – looking right at the animal
  - Aerial surveys
    - Species you can see from the sky (wildebeests, herds of other things, etc). Vancouver Island Marmot was tracked this way when it was critically endangered
    - Visibility is very important – you need to be able to see to count
  - Roadside bird counts
  - Photographs
- Indirect – looking at evidence of the animal.
  - Footprints
  - Vocalizations
  - Nests/burrows
  - Issue – you cannot identify individuals; you can't be sure that you're not counting the same animal twice

Mark Recapture Techniques

- Sampling techniques using an organism to estimate population size
- Lincoln-Peterson (simplest way)
    - Person visits site; captures, marks, and releases as many individuals as possible. It is then possible to identify individuals based on the marks associated with them on a later date. They then wait an appropriate (species-specific) time for the individual to re-integrate with the rest of the group. The animal is then recaptured, and then number of resampled organisms is recorded. The data is plugged into the equation to estimate population size.

$$N = ms/r$$

    - N = population
    - m = number of individuals marked and released
    - s = number of marked and unmarked animals in resampling effort
    - r = number of marked individuals in resampling effort
    - Assumptions:

        1) No effect of marking on probability of recapture
        - Very frequently violated ("Once caught, twice shy").
        - Type of bait may help with this (rodents LOVE peanut butter)

        2) No effect of marking on survival
        - A giant collar may make it a mark for a predator
        - If it is a predator, a big collar may prevent it from being able to capture prey

        3) Mixing of marked and unmarked individual
        - Must be reintegrated back into the population successfully

        4) Marked individuals are representative of whole population
        - All age groups, both sexes, healthy animals

        5) Closed population
        - The area you're looking at doesn't have immigration/emigration – often violated

        6) Marks are not lost
        - Example – ear tags on hippos. They flick their ears when out of the water, and the ear tags may rip out.
        - Trackers (satellite) – battery may die, they may get lost. Design must be good.

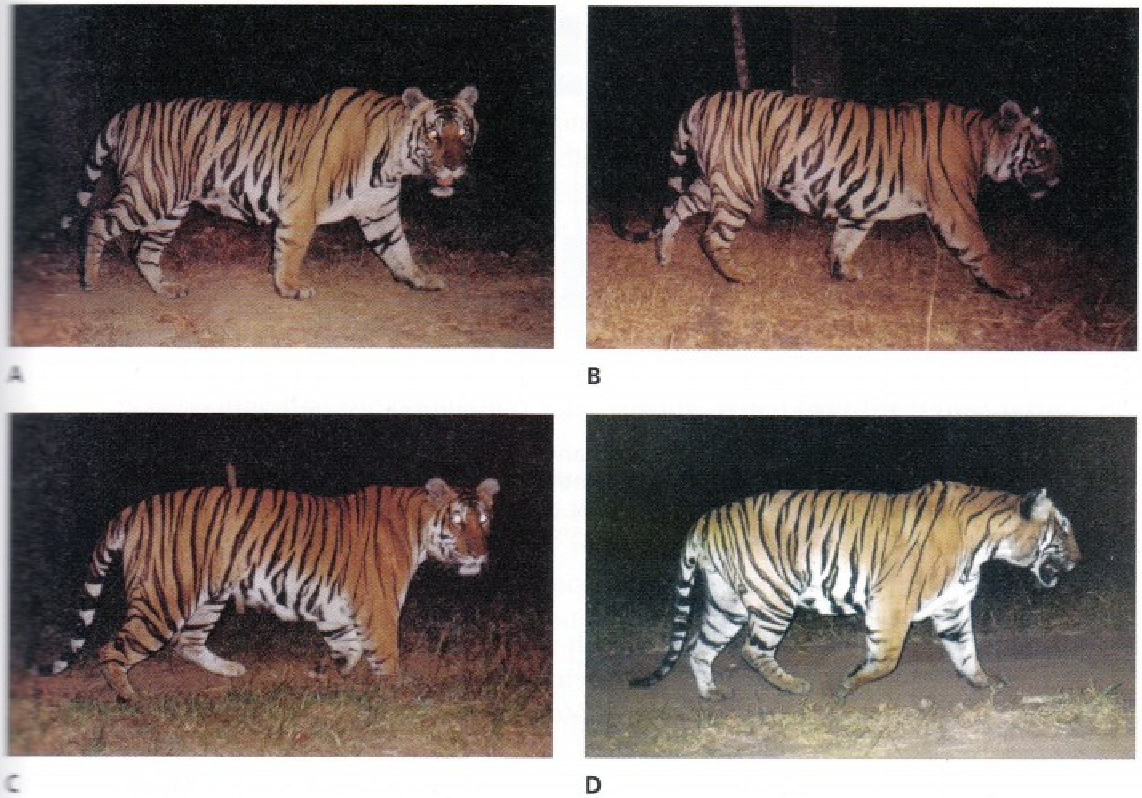


Figure 8.3 Tigers "trapped" in photos. The two upper photos **(A)** and **(B)** are of the same individual, whereas the lower pair, **(C)** and **(D)**, shows two different individuals, as determined by stripe patterns.

- For certain spotted/striped feline species, individuals may be identified by their coat pattern (like a fingerprint, it is unique). Pictures may be good enough to keep track of them. The rate at which individual tigers are rephotographed may be used to extrapolate population sizes.

Estimating Past Population Size

- Use of historical records – see whale example.
- Use of genetic studies
  - Genetic drift happens at a slow rate, and small populations lose genetic diversity slower than large populations - Modern idea, prone to some errors, but may provide a very informative view of past population size.
  - Modern-day genetic diversity correlates positively with historical population size

$$H_t/H_0 = 1 - (1/2N_e)^t$$

- Can assess current heterozygosity of the population, and with this information you can estimate past heterozygosity.

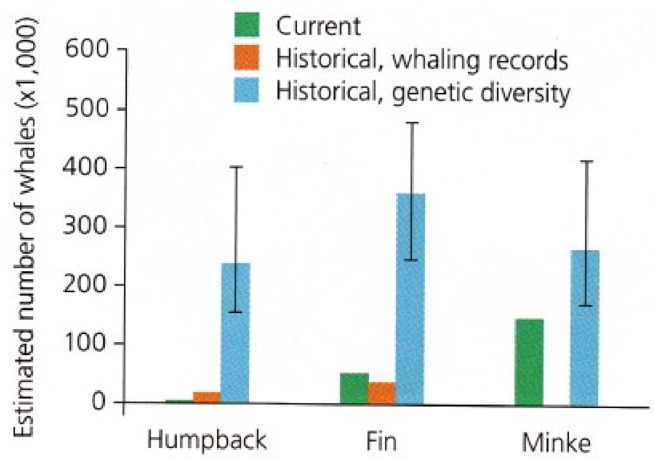


Figure 8.4 Estimates of current and historical populations of humpback, fin, and minke whales in the North Atlantic. Estimates of historical populations by the IWC are based on whaling records. Note that the IWC did not generate an estimate for past minke whale populations. Error bars are 95% confidence intervals. Data are from Roman and Palumbi (2003).

- Historical whaling records were used to estimate previous populations of the whales, but genetic diversity provides a better clue.
- The reason they want to know: Once current populations reach 54% of historical populations, they may be hunted again. Using historical records implies a shorter regeneration time, but using genetic research comes up with a much larger time.
- These are used to inform policy, but may not be seen as positive – Japan wants to hunt whales, and likes the historical method because of the result.

Challenges Of Estimating Trends

- Populations are not static – they are variable over time.
  - When/what time points do you use to estimate trends?
  - Example – Red-cockaded Woodpecker - Sometimes it shows an increase between years, but in general there is a decrease – long-term datasets are important if you want to estimate a trend in the population.
- Long-term datasets are very rare.
- Stochasticity
- Environmental variation
- Pathogens
- Change in predator density

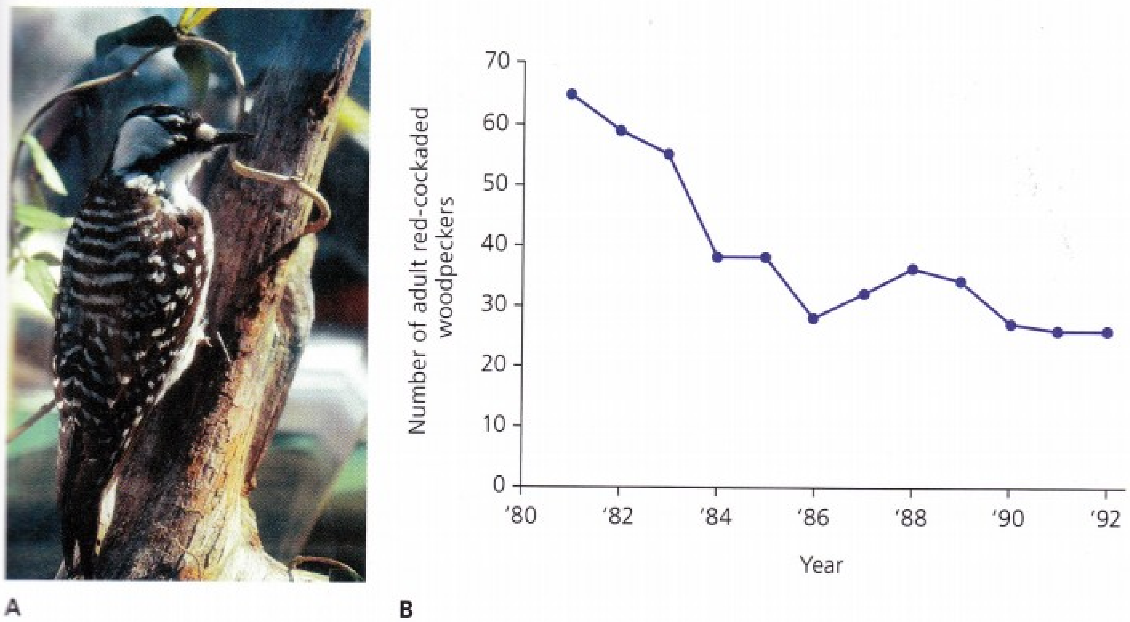


Figure 8.5 **The challenge of estimating population trend. (A) A red-cockaded woodpecker (*Picoides borealis*). (B)** The size of a population of red-cockaded woodpeckers from central Florida, estimated repeatedly through time. After Morris et al. (1999).

Determining Trends vs. Noise

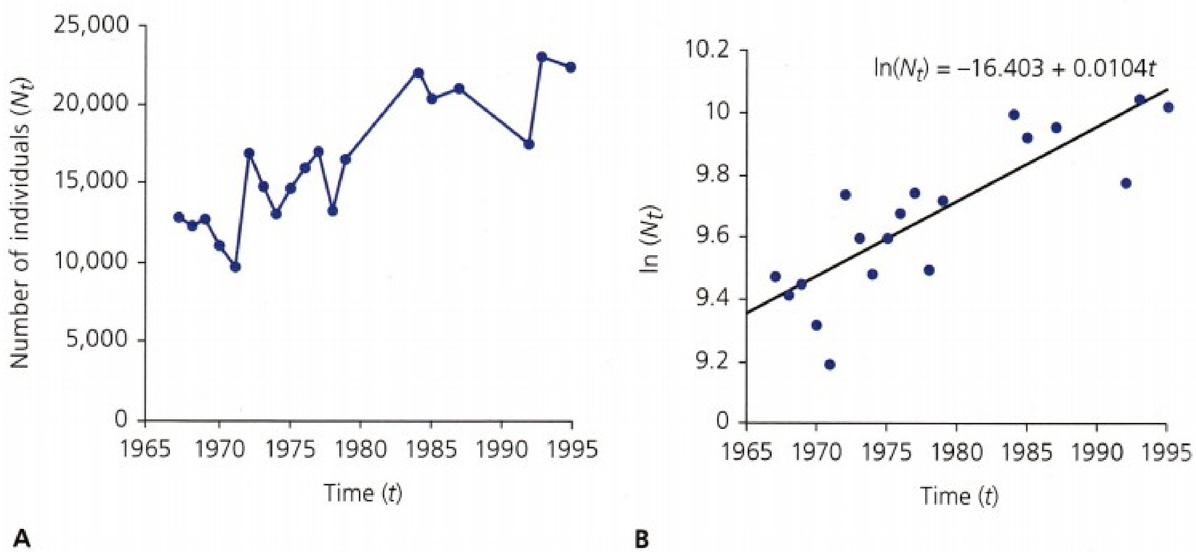


Figure 8.8 **Time series of population size estimates for eastern North Pacific gray whales (*Eschrichtius robustus*). (A)** Estimated population size based on shore-based surveys performed by the NOAA Fisheries Service along the California coast. After Gerber et al. (1999). **(B)** Natural log-transformed population estimates with best fit line based on linear regression.

λ = long-term intrinsic growth rate of population
= e $^{\text{slope of regression line}}$ = 1.0105 (1% increase/year)

- Fitting a line of best fit to a data that has been log transformed

- Slope in this example = 0.0104
- 1% increase/year is very good for whales!
- This is a simple model; we usually work with more complex models when we have more data

Population Viability Analysis (PVA)

1) Estimate of current population size (N)
2) An estimate of population trend (λ)
3) Some information about the degree to which λ varies over time

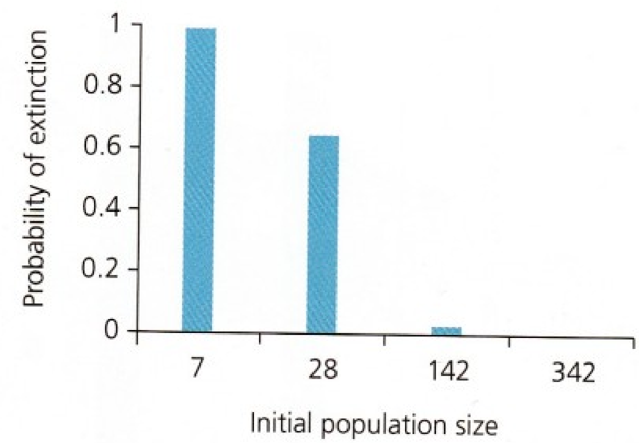


Figure 8.13 The effect of initial population size on the probability of extinction within 1,000 years for Sumatran orangutan populations. Data are from Ellis et al. (2006).

- Plug this data in to software, and it will give you a probability that a certain population will become extinct over a certain period of time
- The more far in the future you go, the less accurate it it going to be, so most PVAs only go 50-60 years into the future
- Variation is possible - "Suppose our initial population size is such and such...what will the probability be then?"

Failure of PVAs

- Data coming out is only as good as data going in
    - The complexity of the model is determined by the amount/quality of data you get
    - Often only an estimate of trend is available
    - Limited – there is uncertainties in the models
    - Cannot account for disease/natural disasters in models
- Example – wolves

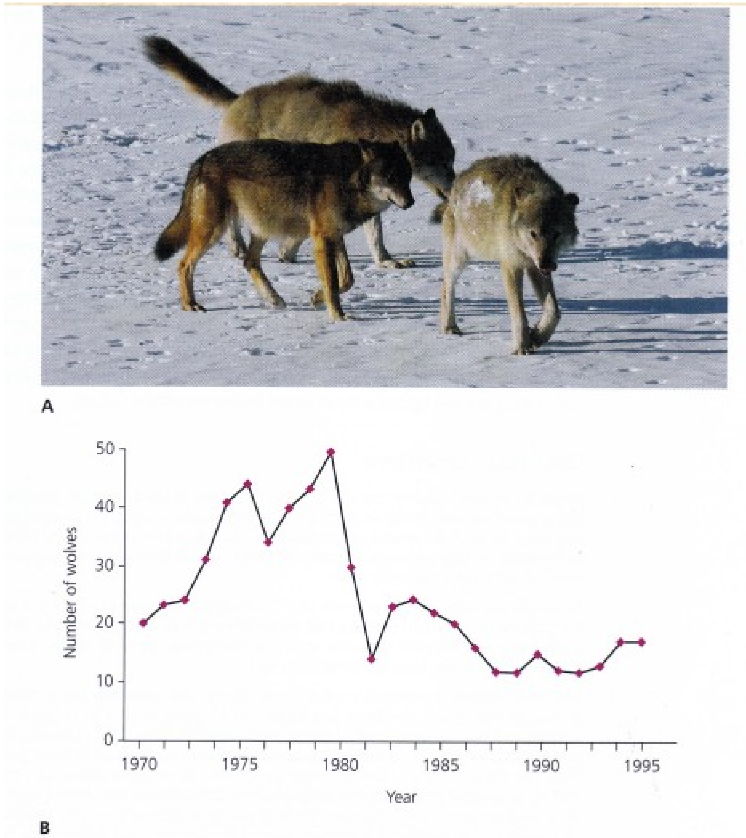


Figure 8.15 A PVA that failed to predict future population dynamics. (A) The population of wolves on Isle Royale, Michigan, was growing rapidly until a disease outbreak in 1980. **(B)** Estimates of the wolf population are based on snow tracking, radio tracking, and direct observation. After Peterson et al. (1998).

- The population looked like it was increasing, but the model could not predict a disease outbreak in the population which drastically lowered the population.

Uses For PVAs

TABLE A Potential Uses of PVA "Products"

Category of use	Specific use
Assessment of extinction risk	Assessing the extinction risk of a single population Comparing relative risks of two or more populations Analyzing and synthesizing monitoring data
Guiding management	Identifying key life stages or demographic processes as management targets Determining how large a reserve needs to be to gain a desired level of protection from extinction Determining how many individuals to release to establish a new population Setting limits on the harvest or "take" from a population that are compatible with its continued existence Deciding how many populations are needed to protect a species from regional or global extinction

- Sea turtles – will helping the offspring survive help the population?
  - They found through PVA analysis that helping the adult survive (mostly preventing them being bycatch) helped the population more than protecting the hatchlings
- PVAs have a large role in developing a conservation plan.

Protected Areas

- Ultimate goal of protected areas – to preserve biodiversity
- There are other reasons why people may protect an area
  - Religious (sacred forest areas)
  - Ecotourism
    - Driving force in many developing countries
      - Africa – has been pushing ecotourism in Botswana for years
  - National Parks
    - Some human use, often have roads/trails
    - Were created to provide tourism opportunities
  - To protect particular species or habitat
    - Often require management (or regular management interventions) – just because humans are involved in this process doesn't mean that it's bad.
  - Working together to meet both goals of sustainable use and conservation
- IUCN has important designations of protected areas.
  - Has multiple categories of protected areas based on how well they are separated from

human impact
    - Strict nature reserves, wilderness areas = next to no human use
    - Habitat/species management areas have human impact to protect species and habitats

BOX 9.1 IUCN Protected Area Management Categories. *Source*: IUCN 1994.

Category Ia:	Strict Nature Reserve: protected area managed mainly for science.
Category Ib:	Wilderness Area: protected area managed mainly for wilderness protection.
Category II:	National Park: protected area managed mainly for ecosystem protection and recreation.
Category III:	Natural Monument: protected area managed mainly for conservation of specific natural features.
Category IV:	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention.
Category V:	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation.
Category VI:	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems.

Ecoregions

- An ecoregion shares environmental conditions and similar flora and fauna
- Percentage of land area protected varies among ecoregions
    - UNEP World Conservation Monitoring Centre
- 18 ecoregions in the world
- In terms of protected areas, they looked at the percentage of each region which was protected under the IUCN
- Higher percentage was saved in areas which had a lower agricultural value
    - Lots of protected areas in mountainous regions, ecotourism
    - The Midwest has a lot less conservation, because of the high potential for agricultural use
- In 1996, there was a call to protect at least 10% of the terrestrial world, and while we now protect ~13%, this is very patchy
- A lot of species have populations in totally unprotected areas.
- Because of the various reasons behind preservation, preserving biodiversity may not be a priority in some areas
    - Conservation planning must take into account human needs

Figure 5.1 Percentage of each ecoregion that is protected. Reprinted with permission from Hoekstra et al. (2010); created by The Nature Conservancy based on data derived from UNEP/IUCN (2007), Conservation Biology Institute (2006), and Collaborative Australian Protected Area Database (2006).

- The total number of protected areas is beginning to slow/level off (see below)
- The areas which are easiest to protect have already been protected (easiest on human needs/wants)
- More difficult to find areas to protect without issues of human-nature conflicts
- More conflicts will continue, and challenge the established areas, as human population increases
- The areas which have been designated as protected **must** have these protections enforced – otherwise, they are "paper parks"/not protected.
    - Most of these paper parks were created without considering human needs
    - Sometimes communities were displaced, which created a negative connotation between the protected areas and the displaced community
    - If you involve local communities in the management of an area, it is less likely to become a "paper park"
    - Make the park economically good for them! Provide jobs, incentives for management, etc.
    - Avoid imperialism! Be sensitive to how local communities are going to react – impressions of conservation are important

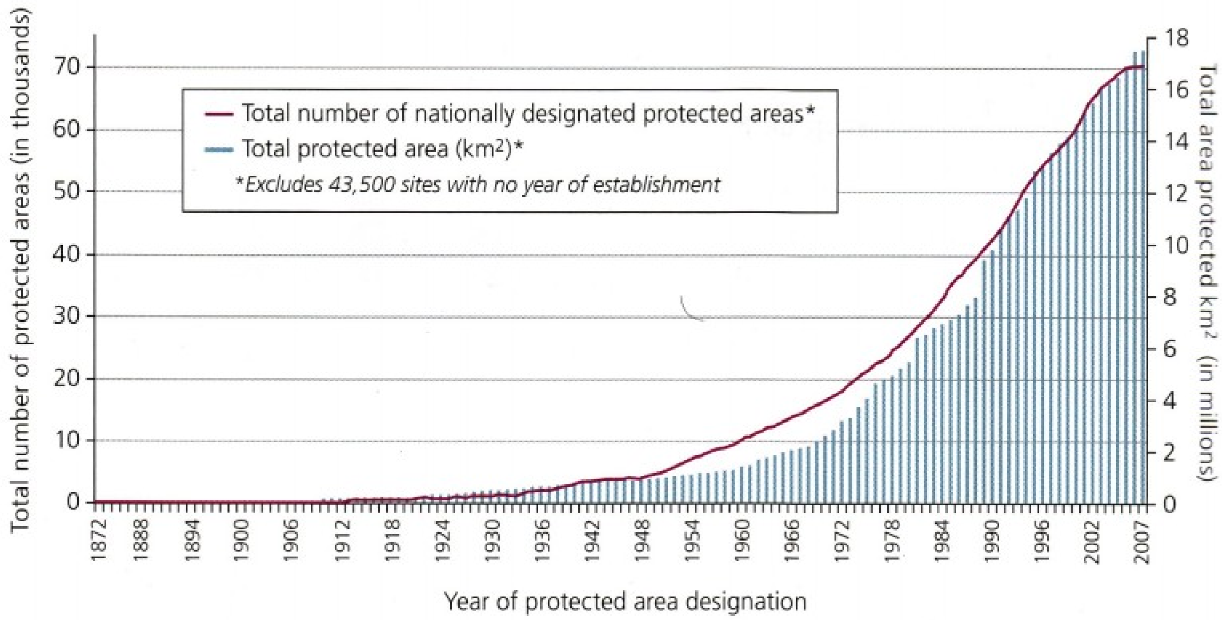


Figure 5.3 Global growth of protected areas. Both the area and the number of protected sites grew rapidly beginning in the 1960s, but that growth has slowed in recent years. Note that an additional 43,500 protected areas covering approximately 4 million km^2 have no known date of establishment and therefore are not included in this graph. After UNEP-WCMC (2008).

Marine Protected Areas

- Have lagged behind terrestrial areas considerably
- conservationalists wanted 10% of the world's oceans protected by 2012, but we are predicted to reach this target by 2067
  - 4% of marine areas are fully protected
  - Some MPAs are “no-take zones” – no harvest/habitat harm is permitted
    - Similar to classes I and II on IUCN
    - .08% of the ocean is protected as a no-take zone
- You can purchase or lease marine areas for protection/use
  - Conservation organizations as well as oil companies do this

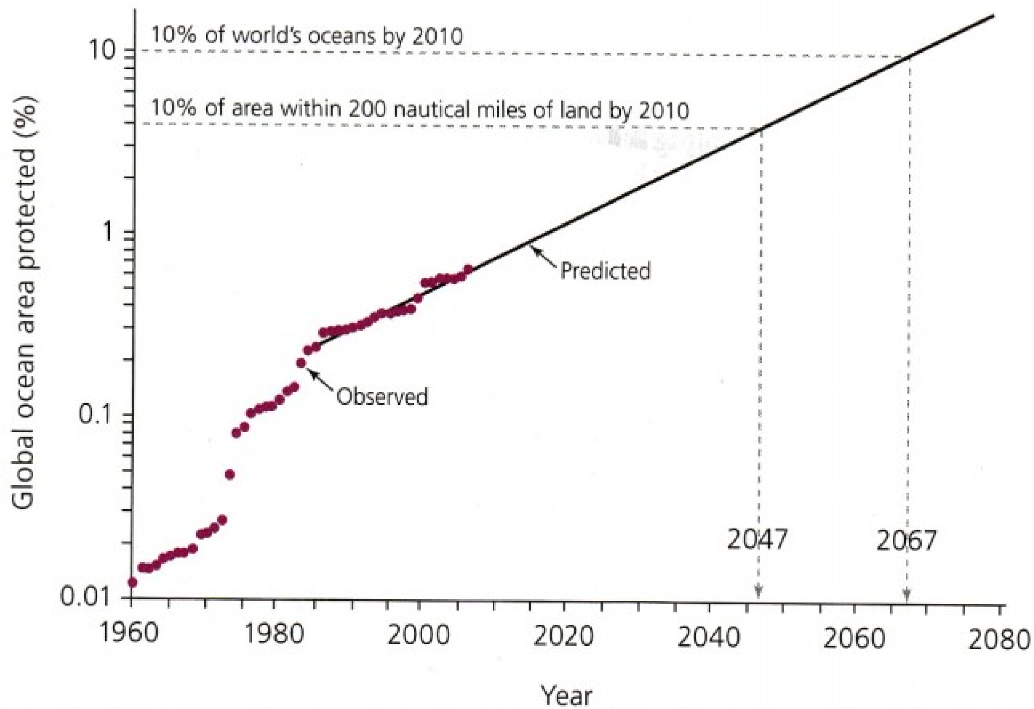


Figure 5.5 Growth in the percentage of the world's ocean area protected within MPAs. If the growth rate between 1984 and 2006 continues, the goals set for 2010 will not be met until decades later. After Wood et al. (2008).

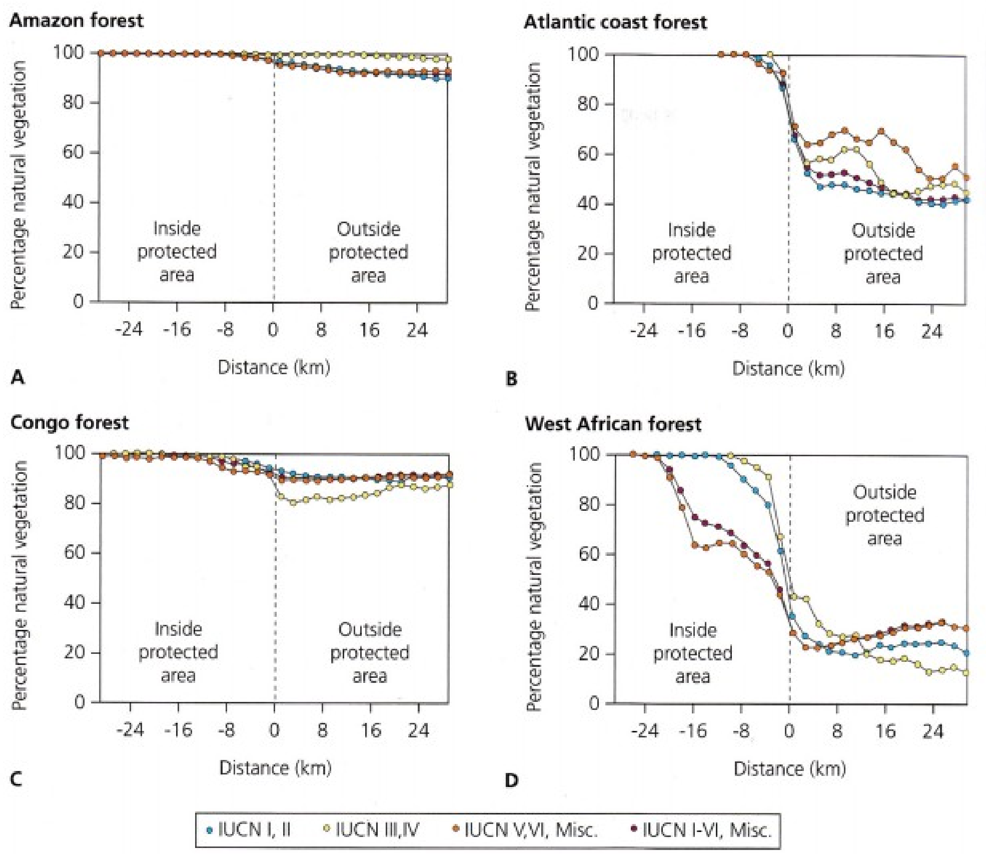


Figure 5.4 Percentage cover of natural vegetation inside and outside protected areas in (A) Amazon, (B) Atlantic coast, (C) Congo, and (D) West African forests. Natural vegetation cover is high both inside and outside of protected areas in the Amazon and Congo forests, but there is a sharp change from high to reduced cover along protected-area boundaries in the Atlantic coast and West African forests. After Joppa et al. (2008).

How Effective are Protected Areas?

- There is much variability in the effectiveness of protected areas
- Maps of natural vegetation do not take into account animals – may have an empty forest, with lots of bushmeat taken.
- Lessons
    - **Enforcement**
        - Money must be available for enforcement
    - **Demarcating Boundaries**
        - Boundaries must be clear and enforceable, or people might violate legislature without realizing it.
    - **Local Compensation**
        - Compensation for their loss in that area (in food, in resources, etc)
    - **Management by locals**
        - Reduce the conflict between conservation needs and local needs

Protection on Private Lands

- **Land trusts**
    - Non-profit organizations who buy or lease land for conservation.
        - Some private landowners may be hesitant to give their land to use by the government,

but will be more willing to work with conservationalists
    - They may manage the land themselves, or work with the government
    - Non-profit organization association – there may be tax breaks involved.
        - This could be a good incentive for getting funding from wealthy people!
    - Locally responsive, and flexible (more-so than the government)
        - May be able to respond to imminent threats faster than the government because they don't have to go through bureaucratic hoops
    - Some governments don't want other countries coming in and protecting local land

- **Conservation Easements (covenants)**
    - Legal contracts restricting activities which harm biodiversity.
    - May lease the rights to use the land, or not use the land
    - The NGO pays the owner so they do not do activities which harm biodiversity, such as developing, graze, log or mine.
    - Buying the rights to restrict the activity, essentially

- **Tradable Development Rights**
    - Landowner of valuable conservation land can sell his or her rights to develop that land to another developer for use elsewhere, and be compensated for not building in conservation region. Purchaser receives rights to build at a higher density on their land than would normally be allowed.

- **Conservation Banking**
    - Landowner enters into agreement with government to protect land in exchange for credit, and can use the credit to compensate for other habitat damage (or sell them to another developer to use to compensate for habitat damage)

- These are relatively new ideas, and there are some issues - what if the person sells the land? How can we reinforce restrictions/more effective monitoring (how do we know if the person won't just use their land anyway)?

<u>Lecture 20 – Conservation Planning</u>

Conservation Planning

- Needs to be something quantifiable, that is measurable and definable
- If people don't like it, they won't buy it.

1) Identify conservation targets
2) Inventory region for the occurrence of targets and threats to them
3) Set conservation goals
4) Design a network of conservation areas

1) Conservation Targets

- Species
    - Must be a measurable target
    - Most environmental legislation focuses on saving species

- Which target you choose is going to change your conservation plan.

    - ***Indicator Species***
        - Presence whose well-being indicates good habitat quality
        - Example – Northern Spotted Owls
    - ***Flagship Species***
        - Species which are very charismatic or culturally valued
        - In the public eye, so using them for fund-raising is an advantage
        - Are often Umbrella species, so may help other species by being protected
    - ***Umbrella Species***
        - Wide-ranging species – if you protect their habitat, you are protecting many other species withing that range

- Does targeting a species indicate biodiversity?
    - Unfortunately, no. But Umbrella species are better at protecting many species, because of the large range which can be affected by their protection.

- Ecosystems
    - Being done in countries where governments create legislation (clear definitions in law)
    - High species richness
    - Ecosystem services
        - Does not always equal biodiversity

2) Inventory region for the occurrence of targets and threats to them

- Where do the targets occur?
- What conditions are those spaces in?
- What are the likely threats and relative importance of each to the persistence or function of the space?
- Gap Analysis Program:
    - Map a distribution of a species or taxon, overlay a map of protected areas, then can identify gaps between where a species is and where it is not protected.
    - The gaps are where conservation efforts should be implemented, and cost-effectiveness of protecting that area should be identified.
    - Decisions limited by the quality of your data – sometimes you can't know the exact distribution of a species, so sometimes the maps concentrate on habitat requirements.

- These maps often have errors, and it is important to estimate your degree of uncertainty.

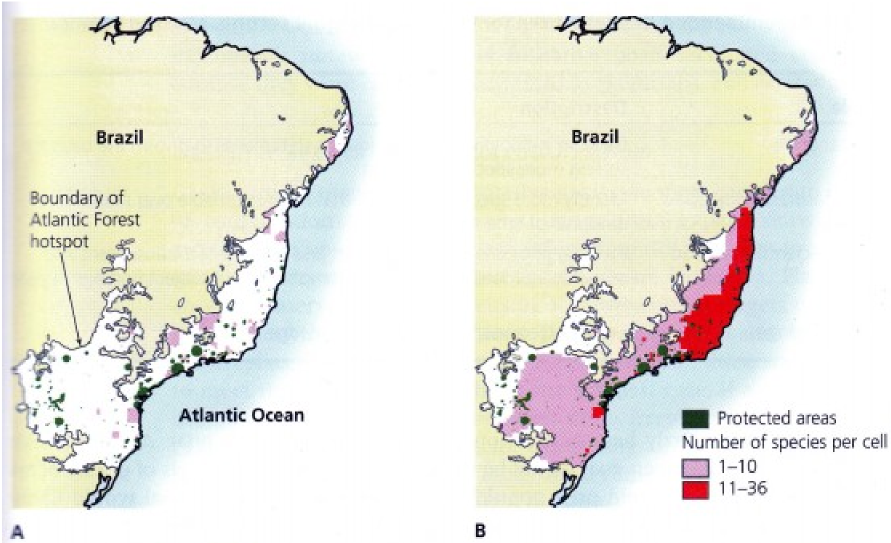


Figure 6.3 Gap analysis for 375 mammal, amphibian, turtle, and threatened bird species endemic to Brazil's Atlantic Forest hotspot. (A) The density of species whose ranges (16% of the total) fall completely outside of protected areas. **(B)** The density of species (36% of the total) for which protected areas cover less than 5% of their range. After Rodrigues, Akçakaya et al. (2004).

- Above example - Brazil
- Globally – 12% of 12,000 mammal, bird, turtle, and amphibian species assessed were found in no protected area, and an additional 12% were in areas that were small (<1,000 ha) or weakly protected (IIUCN categories V or VI)

3) Set Conservation Goals

- Goals must be well defined
- Measurable objectives – to determine whether you are failing or succeeding.
  - How many organisms are enough to secure a species?
    - PVA
  - How much habitat is needed to protect the biodiversity in an area?
- Use the Scientific Method to develop your objectives
- Anticipate change – plans must be able to change based on data coming in.

Table 6.1. Recommended best practices for conservation goal setting. Modified from Tear et al. (2005).

Principle	Description
State clear goals	Develop well-defined, unambiguous statements that form the basis for setting more specific objectives
Define measurable objectives	Identify more specific objectives that are quantifiable over reasonable amounts of time and space
Follow the scientific method	Build on prior knowledge, conduct and document a transparent and repeatable process, document assumptions, and subject findings to peer review
Anticipate change	Expect objectives to change as knowledge is gained

- Goals must be determined by the public and the governmental approval
- Numerical objectives are easy to track and communicate
- Law passed in Florida – Florida Forever Program

- Shall be implemented in measurable state objectives
    - Each vertebrate species in Florida must have 10 breeding populations of 200 individuals on public land.
    - Good example of use of numbers in legislation

4) Design a Network of Conservation Areas

- How to achieve goals with minimal land or protecting the most targets with a fixed budget
    - Cost/benefit analysis
        - Number of species saved in an area/cost of protecting that area
    - The public/government does not want to spend much money
- Site Selection Algorithms: MARXAN/SITES
    - Essential to current site selection, also help with cost-benefit analysis
        - We can be much more efficient with conservation efforts now than even 15 years ago
    - Divide region into spatial sites which may or may not be included in a conservation network
    - Add data associated with each site (depends on targets – ex. Number of organisms or amount of habitat in each site).
    - Newer versions can include site data on threats such as likelihood of conversion to agriculture, urban development, or mining.
    - Searches combination of sites that will meet the conservation goals within the minimal land area, in the most cost-effective method
    - Index of irreplaceability - What potential sites are irreplaceable?
        - If a targeted species only occurs in one area in that region, that region is irreplaceable
        - The more frequently a site comes up, the more irreplaceable it is.
    - Often can display a large number of potential solutions, and you can approach the government with options as to the direction
        - Ask for more than you will receive, because then the policy-makers will feel as though they are being responsible financially/not environmentally-biased while still providing you with as much as you need.

Conservation Planning for Compensation/Migration (Conservation Banking)

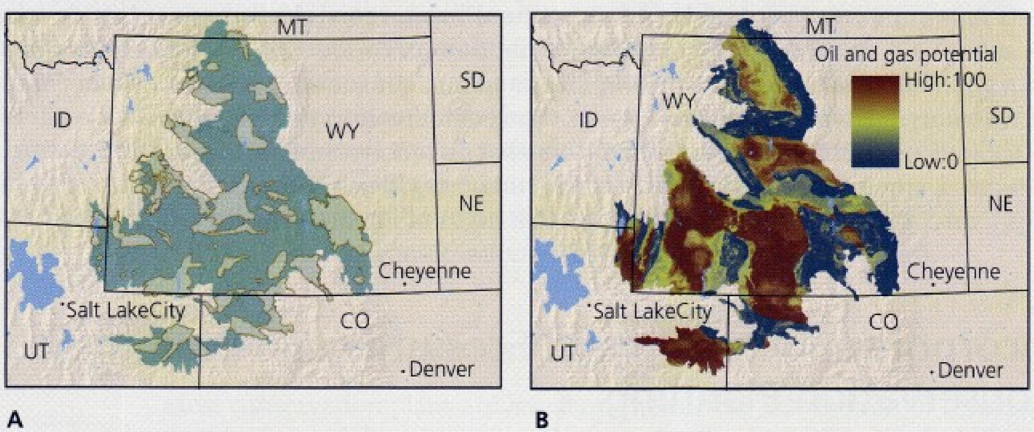


Figure 6.4 Conservation planning and the purchase of biodiversity offsets. (A) The Wyoming Basins ecoregion is shown in green, and high priority conservation sites are highlighted in gray-green. **(B)** Oil and gas potential varies across the ecoregion. Given the vast areas that might yield fuels, opportunities exist to choose among a wide range of drilling locations in a way that avoids the most irreplaceable areas, while focusing mitigation efforts on sites of high conservation value. Reprinted with permission from Kiesecker, Copeland, Pocewicz, and McKenney (2009).

- Conflict between conservation and oil and gas needs
- If the company goes there, there will be a huge impact on many species
- They can look for suitable alternative areas which the company can use
  - What sites are comparable to those disturbed?

Table 6.2. Mitigation goals for key conservation targets that would be affected by expanded natural gas production in Jonah Field, Wyoming. The goals are stated in terms of areas likely occupied by the target species that will be impacted by energy development and thus must be offset elsewhere. Data from Kiesecker, Copeland, Pocewicz, Nibbelink, et al. (2009).

Conservation target	Goal (ha)
Burrowing owl	13,690
Cedar Rim thistle	3,433
Mountain plover	1,390
Pronghorn migration	7,738
Pygmy rabbit	7,436
Sage grouse (winter/nesting habitat)	21,043
Sage sparrow	8,813
White-tailed prairie dog	1,705
Wyoming big sagebrush	22,573

Table 6.3. The value of six potential sites that might be used to offset damages at the Jonah Natural Gas Field, Wyoming. The mitigation value of each site is quantified in terms of its ability to meet each of the goals shown in Table 6.2. A value greater than 100% indicates that the mitigation site exceeds the goal for the species in question. Data from J. Kiesecker (personal communication).

Site	Burrowing owl	Cedar Rim thistle	Mountain plover	Pronghorn migration	Pygmy rabbit	Sage grouse	Sage sparrow	White-tailed prairie dog	Wyoming big sagebrush
A	14%	0%	24%	43%	123%	32%	11%	111%	32%
B	0%	1%	1%	0%	73%	1%	2%	0%	7%
C	60%	0%	0%	68%	156%	70%	0%	480%	50%
D	0%	0%	0%	1%	5%	1%	0%	3%	1%
E	1%	0%	0%	1%	3%	1%	0%	6%	1%
F	1%	0%	0%	2%	2%	1%	0%	9%	1%

- The software can be used to determine how much the company must compensate conservation efforts for using a certain area (they use a certain amount in one area, and must actively conserve/restore the same amount in another area)
  - Mitigation – must pay for restoration

Conservation Planning for Other Applications

- To minimize conflict with other land uses
  - Choosing the best sites globally while still minimizing agriculture/biodiversity protection conflict (Ceballos 2005 – Carwardine 2008)
    - 11% of earth surface must be protected to protect all these mammals, but many overlapped with crop production/human use.
    - By using the algorithms, they found that the area of conflict between agricultural use and mammals was halved and the total area needed to be protected increased by only 2%.
- To determine the best sites for biodiversity and ecosystem services
  - Good for compromise – what makes all stakeholders happy?

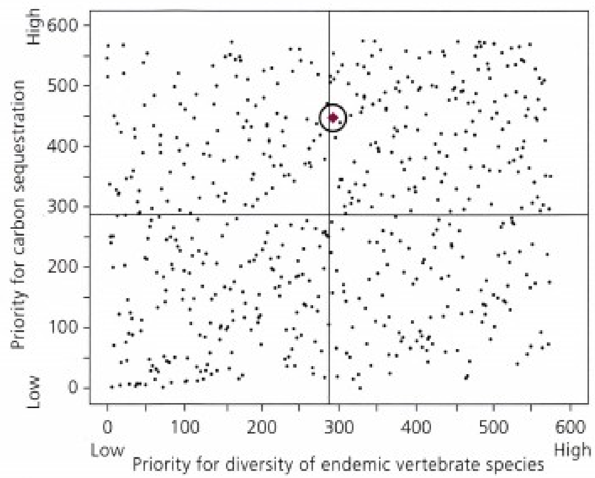
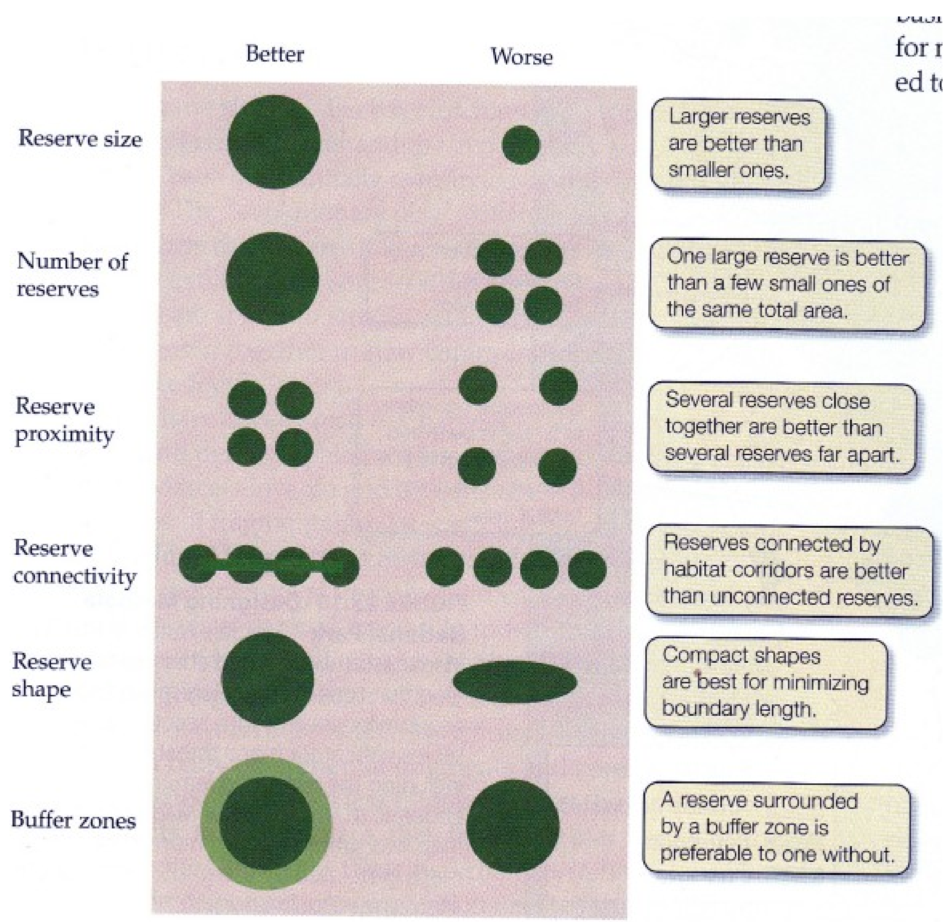


Figure 6.5 Relationship between biodiversity and ability to provide the ecosystem service of carbon sequestration. Each axis shows the rank order of 574 terrestrial ecoregions in per-area carbon storage (*y*-axis) or area-corrected number of endemic vertebrate species (*x*-axis; calculated as the number of endemic species /area$^{0.25}$). Lines indicate median ranks for each variable. The circled diamond represents California's Central Coast ecoregion, highlighted because it has been examined in a similar way, but at a finer spatial scale. After Naidoo et al. (2008).



Designing Conservation Areas – Spatial Configurations

- One large better than a few small – SLOSS debate

SLOSS – Singe Large Or Several Small

- Island biogeography suggests smaller areas have fewer species in lower abundance
- Yet, habitat fragments are not exactly like islands – they have land between them, forming a matrix that animals can cross
- Single large reserves are better if species are nested, but several small is better is fragments have unique species assemblages
- Nested: all in smaller area are located in large
  - When there is a high overlap a large area is better
- Connected habitats (corridors) are better than isolated
  - Especially for animals with large habitats, and those which migrate
- Reserves close together are better than those far apart
  - Animals can travel between – gene flow

Fate of Amazonian Forest Fragments

- The historical, unfragmented biodiversity was unknown
- Long term studies over a large area – 34 years, 1000km
  - Impacts of fragmentation, corridors etc. could be measured
- We want shapes which minimize boundaries compared to core, to reduce edge effects
  - Edge effects are one of the most important drivers of ecological change in fragments
    - Impact 10-300m into the core
  - Buffer zones are helpful surrounding the core – edge effects will occur here and not in the core
    - Core = no human distrubance
    - Buffer = limited human use (hiking, fuel/wood harvest)

Restoration Ecology

- Applies the principles of ecology to the practice of restoration (assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed)
- Very expensive!
  - Restoring flora is easier than restoring fauna
  - Damage can be caused through mining, logging, oil spills etc.
    - Re-establish
      - Site topography
      - Hydrology
      - Soils
      - Re-vegetate
    - (Bio) Remediation
      - Active removal of pollutants from environment (using bacteria or plants)
      - We don't have a lot of information about the importance of microbes in soil restoration
- Need Clear Objectives (reference state)
  - Habitat restoration for a species, replacement of ecosystem function, recreation of historical conditions, enhancement of habitat/ecosystem service (monitoring – adaptive management)

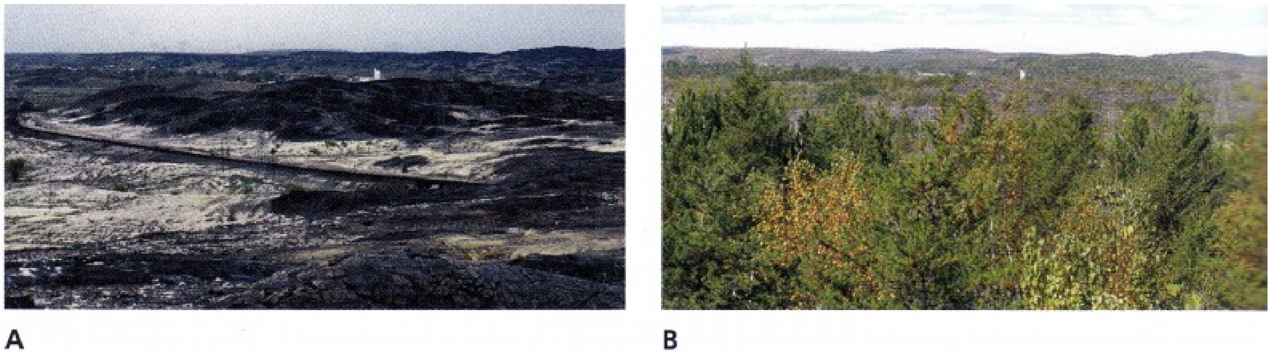


Figure 11.2 Photos of an area near Sudbury, Ontario in (A) 1981 and (B) 2008. The area was denuded by sulfur dioxide emitted from a nearby smelter. Applications of ground limestone restored soil pH and allowed recolonization by many broadleaf tree species to occur unaided.

Actively Restore, or Let Nature Take Its Course?

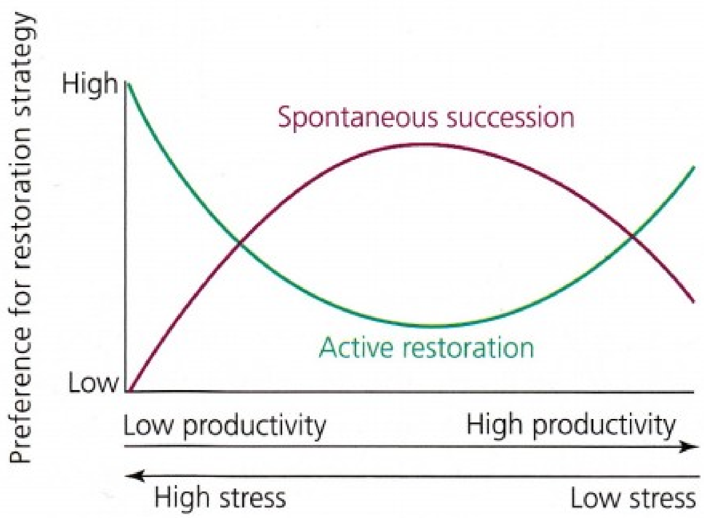


Figure 11.3 A conceptual model predicting conditions under which succession will proceed on its own (spontaneously) as opposed to requiring active restoration. After Prach and Hobbs (2008).

<u>Lecture 21 – Ex Situ</u>

Animal Reintroduction/Translocation

- More expensive than recreating habitat
- IUCN Guidelines
    1) Feasibility study
        - Are you introducing the animal to a similar habitat? How similar?
        - What species will be impacted?
    2) Site evaluation/threat assessment
        - Is this area in the historic range?
        - Why was the species extirpated?
        - What threats exist in the area
    3) Identify and evaluate suitability of stock

        - How genetically diverse is the source population?
    4) Evaluate social, political, and economic conditions
        - Translocation may become more popular because of climate change
        - Do you have long-term financial and political support?
    5) Monitor with stakeholders to obtain cooperation, pre and post monitoring
        - Minimizing conflicts between humans and wildlife (especially predators)
    6) Post-release monitoring for adaptive management
        - Were we successful?
        - We can get animals from the wild (where populations are too high)
        - Need people with knowledge of species to monitor the impacts of introduction
        - For critically endangered populations, zoos are often relied on

Ex situ Conservation – Role of Zoos and other Ex Situ Facilities

- Public education/outreach – fostering a love of nature
- Research populations
    - Breeding in captivity is a learning curve – we lose some members of the population (and therefore genetic diversity) when animals die while we learn how to breed them.
    - Polar bears do not breed well in captivity – it is not looking good for the population in the future
    - We are much better at breeding tigers and rhinos in captivity
- In situ conservation
- Source of organisms for reintroduction – captive breeding
- Safety net
    - It is not feasible to just conserve animals in the wild any more.
    - Maintain the genetic diversity of the species

World Association of Zoos and Aquariums (WAZA)

- IUCN – Conservation Breeding Specialist Group (CBSG)
    - World Zoo and Aquarium Conservation Strategy (2005)
    - Focusing on maintaining research populations in case they are needed for reintroduction

Regional Zoo Associations

- AZA, CAZA, EAZA, BIAZA, PAAZAB, ARAZPA, AMACZOOA, JAZA, SEAZA
    - American Association of Zoos and Aquariums (aza.org)
        - Accreditation Program – AZA's standards for animal management and care, including living environments, social groupings, health and nutrition, enrichment, involvement in conservation and research, education programs, safety policies and procedures, security, physical facilities, guest services, and the quality of the institution's staff, institution finances, its governing authority, and its support organization.
- Taxon Advisory Group (TAG)
- Species Survival Plans (SPP)
    - Cooperatively manages specific, and typically threatened or endangered, species population with AZA accredited zoos and aquariums. Certified related facilities, and approved non-member participants
    - Overseeing the development of a Studbook
        - Maintain at least 90% of the genetic diversity in a species for the next 100 years

        - Polar Bear studbook
            - Advisor in charge of the studbook
            - Small Population Management Advisory Group
            - Specimens may be excluded because they are too young or too old
            - Mean generation time
            - 42 founders
            - Demographic populations are limited
            - Infant mortality is very high
            - Interbirth interval is incredibly lengthy – much longer than in the world
            - Ideally, we do not want to do reintroduction – incredibly expensive
    - Establishing management, research, and conservation priorities
    - Developing a breeding and transfer plan with PMC
    - Developing non-breeding plans, in coordination with the Wildlife Contraception Center (WCC)
    - Serving a specific role in conflict resolution issues that may arise
    - Collaborating with other institutions/agencies to ensure integrated conservation initiatives
    - Increasing public awareness of wildlife conservation issues
    - Developing and implementing ex situ and in situ education strategies
    - Developing in situ reintroduction programs, if possible.

De-extinction?

- Somatic cell nuclear transfer
    - Somatic cell nucleus transferred to enucleated oocyte
        - From where do we get the oocyte?
            - Skin cell, mammary gland cell
            - Full genetic compliment
        - How do we mature it?
            - Place it in a uterus!
        - What species?
            - An elephant is not a cow, a wolf is not a sheep
    - Stimulated to divide to get embryo
        - How?
        - What culture conditions?
        - Then what?
            - For mammals, what species has a suitable uterus?
                - Tasmanian wolf – which species?
                    - Tasmanian devil – not that closely related, also having a population crisis
                - Mammoth – Elephant
                    - We do not know how to take oocytes from living elephants, therefore we must slaughter them
                    - Should we ethically bring back mammoths? There may not be any environment for it left, and we are having a hard enough time protecting the elephant.
                    - We should discuss the implications now, before we develop the technology
            - Do we know how to manipulate the endocrine environment suitable for

implantation?
    - Manipulate the ovarian cycle of the animal – we don't know how to do that yet.
        - We need the embryo to implant properly
        - We don't have the information to determine this for species, and likely won't for the next 20 years
- To produce a viable population of a previously extinct animal, there will need to be genetic samples from many individuals to create genetic diversity in the cloned population
    - VERY high mortality/failure rate for this technology currently
    - We are freezing tissues currently to use in the future
    - This should be used when a genetically valuable individual (a founder animal) dies, and we need to replace it – not to increase numbers!

Required Reading Questions

What Every Conservation Biologist Should Know About Human Population

- **What is the current trend in human population numbers?**
    - Human population started increasing after the Industrial Revolution as a result of better health care/water supplies/sanitation/hygiene/living conditions – in the 1800s, the human population began to rise as mortality declined.
    - Human growth rate peaked in the 1960s
    - The human growth rate declined because fertility began to decline.
- **When/why has this changed?**
    - The human growth rate declined because fertility began to decline.
    - Pattern of population change – **Demographic Transition**
        - Path to a stable, larger population characterized by low mortality and fertility.
- **What is the human population predicted to maximize at and when?**
    - Expected to maximize at 10.1 billion in 2100.
- **What are the 3 main policies/programs conservation biologists should support to constructively approach the issue of human population?**
    - Maintain support for family planning
    - Focus on population distribution and composition
    - Address consumption separately from population size
        - AND encourage constructive dialogues

What Is a Species?

- **List 3 isolating mechanisms mentioned**
    - Very different genetic programs (sperm and egg cannot create viable embryo)

  - Behaviours which lead member of a species to shun individuals from other populations
  - Different breeding times/places – breeding contact never occurs
- **What is Gould's argument against the idea that evolution is too slow for us to define a species?**
  - The decision to name a species lies with human taxonomists, not dictated by nature
  - They are still capable of interbreeding with other subpopulation of the species, and are, therefore impermanent and subject to re-amalgamation

<u>Beta Richness</u>

- What is the relationship between habitat heterozygosity and beta richness?
- Differences in beta richness of ants is consistent with Janzns's argument how?
- Describe the 2 kinds of beta richness.
- Describe how understanding the beta richness of an area can help inform conservation in terms of establishing reserves?

Estimating Ecosystem Services in Southern Ontario

- Describe the "value (or benefits) transfer" approach to estimating ecosystem services.
- Describe three challenges to estimating services mentioned in the report.

IUCN.org

- **What is the central mission of the IUCN?**
  - Conserving biodiversity
- **When was the IUCN founded?**
  - 1948 as the world's first global environmental organization
- **What are the 3 key priorities for the IUCN?**
  - Science - Valuing/conserving nature
  - Action - Effective and equitable governance of nature's use
  - Influence - Developing nature-based solutions to global changes in climate
- **What are the categories of threat classification used by the red list?**
  - LC – Least Concerned
  - NT – Near threatened
  - V – Vulnerable
  - EN – Endangered
  - CR – Critically endangered
  - EW – Extinct in the wild
  - EX - Extinct

<u>EDCs Conservation and the Future</u>

- What pathological condition of gonads is found in many fish exposed to EDCs?
- What are the two fundamentally different ways EDC contaminants can affect organisms? Give an example of each that was observed in alligators.

<u>Orca Pollution</u>

- Which sex has higher levels of PCBs and why?
- Provide a hypothesis as to why transient killer whales have higher levels of PCBs than resident killer whales that is related to their different diets

Bushmeat Crisis

- What life-history characteristic is key to sustainable trade in wildlife for bushmeat?
- Describe the BCTF (Bushmeat Crisis Task Force).
- What are the four areas of engagement the BCTF has prioritized?
- What are the three leading success indicators directly related to bushmeat that are employed by the CFBP for landscape management efforts?
- Describe COMACO project and why it is innovative?

Rarity Value and Species Extinction: The Anthropogenic Allee Effect

- What is the theory by which harvesting usually occurs (in terms of the relationship between economic extinction and ecological extinction)?
- The anthropogenic allee effect is similar to what in economics?
- The AAE is founded on what two assumptions?

Understanding the Impacts of Species Invasions

- Describe the three categories of invading species that make them have impacts out of proportion to their size or density.
- Explain why islands appear to be particularly susceptible to invaders

Climate Envelope Models

- What are species distribution models?
- What factors are not usually taken into consideration in climate envelope models?
- What can climate envelope models NOT incorporate in terms of species-specific data?

PVA and Conservation

- What are 3 assessment uses of a PVA?
- What are 5 management uses of a PVA?
- What are the differences between a count-based PVA, a demographic PVA, and a spatially explicit individual-based PVA?
- What makes multi-site PVAs particularly prone to uncertainty?
- What should you use as a guide to which PVA to perform?
- What 3 common-sense practices can be used to improve the use of PVAs?

Black-footed Ferrets

- Describe the primary cause of the decline in the Black-footed Ferret.
- What was the secondary cause of the Black-footed Ferret decline?
- What are the challenges associated with the captive breeding program of the Black-footed Ferret?
- What strategies were tested to increase post-release survival?

Bonus Question!

- Allan Savory – Combating Desertification
- Max increase to grade – 2% (manage time effectively)
- TED seminar (20 mins)
- **Question:** Write a review and critique the ideas proposed by Allan Savory

Final Exam

- Same format as midterm - ~35 percent of it will be from before the midterm
- EXTINCTION VORTEX IN DETAIL!
- At least 30% of the questions will be from the required readings (pre and post midterm)

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Sam Jenny Diana Mitchelmore and Gabrielle friend?