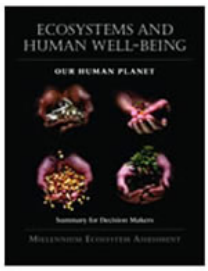
Millennium Ecosystem Assessment

http://www.millennium assessment.org

- 2005 Landmark study by 1300 experts from 95 countries.
- Reports that humans have disrupted ~60% of earth's ecological systems to meet demands for food, water, timber and fuel.

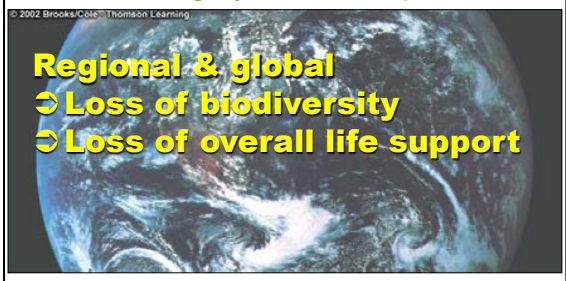


Millennium Ecosystem Assessment

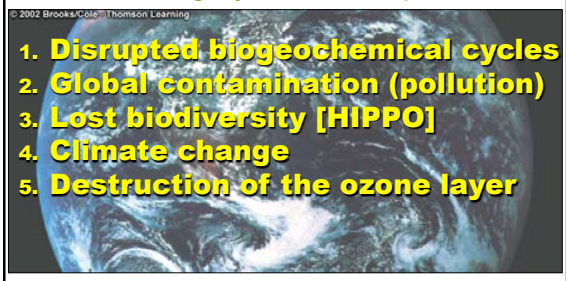
http://www.millennium assessment.org

- "Any progress achieved in addressing . . . poverty and hunger, health and environmental protection is unlikely . . . if most of the ecosystem services on which humanity relies continue to be degraded."
- "Human activity is putting such strain on the natural functions of earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted."
- Slowing this trend "will require radical changes in the way nature is treated at every level of decision-making."

Real and potential human insults to the integrity of the biosphere



Real and potential human insults to the integrity of the biosphere



Ecology and Environmentalism

- The **precautionary principle**

- Basically states that humans need to be concerned with how their actions affect the environment
- It is a lot more plausible to prevent environmental degradation than to try to remediate it

Disrupted biogeochemical cycles

- Water cycle
  - Desertification; contamination; saltwater intrusion
- Nitrogen cycle
  - Nutrient depletion; cultural eutrophication; nitrite contamination; acid rain
- Carbon cycle:
  - Excessive CO_2; depleted fossil pools
- Soils:
  - Erosion; nutrient depletion; fire suppression

Pollution

Pollution

- Contamination of the
  - **Air**
  - **Water**
  - **Soil**
- Contamination by
  - **Toxic chemicals**
  - **Infectious agents**
  - **Excessive eutrophication**
  - **Physical factors**
    - **Thermal**
    - **pH**
    - **Light**
    - **Acoustic**
    - **Radioactive**
    - **Fouling / clogging / burying**

Biodiversity Crisis

Birds

13% of known bird species worldwide are threatened with extinction.

Density of songbird populations has dropped by 50% in the US in the last 40 years.

Biodiversity Crisis

Plants

In the US, 200 species of plants have disappeared within the past 100 years. Another 730 species are endangered.

Biodiversity Crisis

Fish

About 20% of the known freshwater fishes in the world became extinct during historical times, or are now threatened.

About 200 of the 300 species of cichlids in lake Victoria are gone due to introduction of the exotic Nile perch.

Biodiversity Crisis

Since 1900,

- **123 freshwater vertebrate and invertebrate species have become extinct in North America, and hundreds more are threatened.**
- **Extinction rates of aquatic species are five times that of terrestrial.**

Biodiversity Crisis

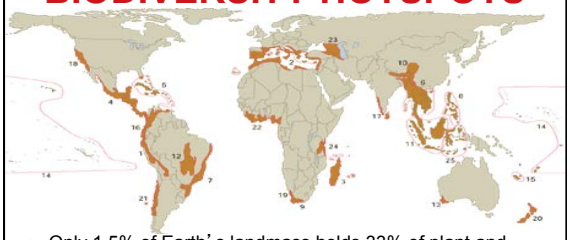
Since 1900, the current rate of extinction is 100 to 1000 times "background" rates of prior centuries

The Anthropocene may represent the greatest extinction event of Earth's history!

Human Benefits of Species and Genetic Diversity

- Species related to agricultural crops can have important genetic qualities
  - For example, plant breeders bred virus-resistant commercial rice by crossing it with a wild population
- In the United States, 25% of prescriptions contain substances originally derived from plants
  - For example, the rosy periwinkle contains alkaloids that inhibit cancer growth

TOP (BOTTOM?) TWENTYFIVE BIODIVERSITY HOTSPOTS



- Only 1.5% of Earth's landmass holds 33% of plant and vertebrate species
- Many of these hotspot species are endemic
- One third of these hotspots have already lost >90% of their area to human development

Biodiversity Crisis

HIPPO

- **H**abitat destruction & fragmentation
- **I**nvasive species
- **P**ollution
- **P**opulation (human)
- **O**verexploitation

Some local species at risk

Bald eagle

Southern sea otter

Ohlone tiger beetle

Santa Cruz long-toed salamander

Habitat destruction & fragmentation

Reduction or loss of natural habitat by

- **housing & industrial developments**
- **agriculture**
- **overgrazing**
- **urbanization**
- **deforestation**
- **mining**
- **oil drilling**
- **fire**
- **erosion etc.**

Habitat Loss

- Human alteration of habitat is the greatest threat to biodiversity throughout the biosphere
- In almost all cases, habitat fragmentation and destruction lead to loss of biodiversity
- For example
  - In Wisconsin, prairie occupies <0.1% of its original area
  - About 93% of coral reefs have been damaged by human activities
  - More than 50% of wetlands in the contiguous United States have been drained and converted to other ecosystems

Fragmented Habitats

- Partial destruction of habitat into patches isolates sub-populations
- Less than 10% old growth forest remains in the US Pacific NW

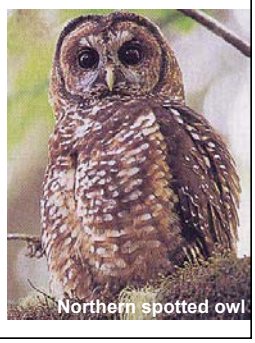
Fragmentation of forest by logging

Habitat fragmentation in the foothills of Los Angeles.

Fragmented Habitats

Quality of Patches Determines Subpopulation Survival

- **Source habitat**
  - Reproduction exceeds deaths
  - High quality patch: old growth forest
- **Sink habitat**
  - Deaths exceed reproduction
- Number of source habitats decreasing



Northern spotted owl

Case Study: ***Habitat Fragmentation and the Extinction Vortex in the Greater Prairie Chicken***

- Populations of the greater prairie chicken were fragmented by agriculture and later found to exhibit decreased fertility
- To test the extinction vortex hypothesis, scientists imported genetic variation by transplanting birds from larger populations
- The declining population rebounded, confirming that low genetic variation had been causing an extinction vortex

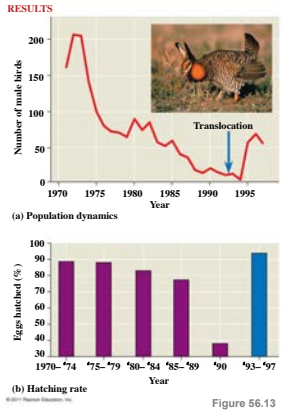


Figure 56.13

LOCAL EXAMPLES OF HABITAT LOSS & FRAGMENTATION

SALT MARSH HARVEST MOUSE

- **Found only in salt marshes ringing SF Bay**
- **Federally and state listed as endangered**
- **About 90%+ of salt marshes have been lost to development & salt ponds**

LOCAL EXAMPLES OF HABITAT LOSS & FRAGMENTATION

PRESIDIO MANZANITA

- **Shrub found today only on north end of S.F. peninsula**
- **Just ONE plant remains, in the Presidio**
- **Former range is now under S.F. itself**
- **Federally and state listed as endangered**

LOCAL EXAMPLES OF HABITAT LOSS & FRAGMENTATION

BURROWING OWL

- Lives in burrows usually dug by ground squirrels
- Flat, open land around SF Bay is preferred territory
- Also preferred by developers!
- Owl was to be listed as threatened, but CA DF&G denied appeal

INVASIVE SPECIES CHARACTERISTICS

Invasive exotic species are bad news because they tend to be

- Competitive
- Quick reproducers
- Adapted to human disturbance
- Adapted to most domestic animal disturbance (grazing, trampling etc.)
- Rapid dispersers
- Without their native predators
- Just overall "weedy"

INVASIVE SPECIES

- Introduced species that gain a foothold in a new habitat
  - Usually disrupt their adopted community

Brown tree snake, introduced accidentally to Guam in cargo

INVASIVE SPECIES

Kudzu ("foot-a-day") — deliberately introduced to SE US

LOCAL EXAMPLES OF INVASIVE SPECIES

WILD PIG

- Introduced to CA in 1930's for hunting
- Now found throughout lower elevation hills, from the coast to Sierra
- Will eat anything it finds--bulbs, fawns, acorns, snakes etc. etc.
- Considered one of California's most destructive exotics

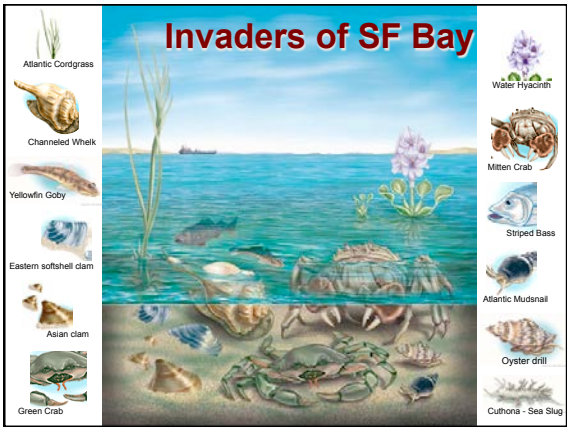
LOCAL EXAMPLES OF INVASIVE SPECIES

YELLOW STAR THISTLE

- Originally from Europe, introduced accidentally
- Almost impossible to control or eradicate
- Out-competes all native grasses and forbs
- Now covers over 7 million acres in California

MORE EXAMPLES OF CALIFORNIA'S INVASIVES

- Eucalyptus (trees, Australia)
- French broom (shrub, Europe)
- Medusa-head grass (Europe)
- *Ailanthus* ("tree of heaven," China)
- House mouse (Europe, Asia)
- Chinese mitten crab (Asia)
- Northern pike (fish, eastern US)
- Starling (Europe)
- English sparrow



Invaders of SF Bay

- The invasive **Asian clam**, *Corbula amurensis*, has changed the food web in San Francisco Bay estuary by severely restricting phytoplankton blooms in the northern embayment

LOCAL EXAMPLES OF POLLUTION PROBLEMS

CALIFORNIA CONDOR

- Captive breeding program is successful, but reintroduced birds now have high lead levels, likely from ingesting bullet fragments in scavenged food.
- Several reintroduced condors have died from drinking ethylene glycol (antifreeze) in contaminated puddles.

LOCAL EXAMPLES OF POLLUTION PROBLEMS

RED-LEGGED FROG

- Many male frogs are now intersex in some ponds polluted with atrazine.
- Atrazine is the most widely used, potent agricultural weed-killer in the US.

POPULATION (OURS)

- California's population is about 35 million.
- It's expected to double within 50 years.
- Human pressures are at the base of most of our conservation problems.

OVER-EXPLOITATION OF WILD "RESOURCES"

- Clear-cutting of forests

OVER-EXPLOITATION OF WILD "RESOURCES"

Fish

- "Factory ships" with fleets of fishing boats cruise from area to area, moving on when nothing left worth catching
- Stocks of large food fish (tuna, shark, grouper, swordfish etc.) have declined to just 10% of their numbers of 20 years ago due to over-fishing.

OVER-EXPLOITATION OF WILD "RESOURCES"

- Sharks worldwide are threatened by the shark fin industry. Typically, only the fins are taken; the rest of the shark is discarded.
- Sharks are slow to mature and produce few young
  - All shark fisheries crash quickly

By-catch

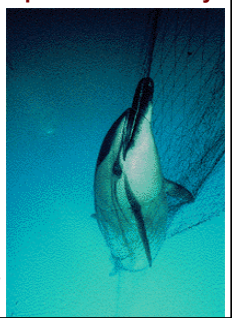
Often, species other than those targeted by modern fishing fleets are caught too. This is called by-catch. These animals are discarded, and add to the depletion of marine species.

albatross caught on longline

By-catch

- In some cases these by-catch species are already endangered.

- Sea turtle caught in a trawler netting. It may take a turtle an hour or more to drown.
- Drift nets may be the leading cause of mortality today of marine mammals such as dolphins, whales and seals



OVER-HARVEST OF SPECIES IN CALIFORNIA

ABALONE

- Despite strict regulation and monitoring, all species of abalone are in decline. Two are nearing extinction.
- Most taken illegally are exported to Asia.

OVER-HARVEST OF SPECIES IN CALIFORNIA

BLUE OAKS

- **Blue oak woodlands are being devastated in the Sierra foothills by development and cutting for firewood.**
- **In many cases, woodcutters "poach" trees from private and public lands.**

OVER-HARVEST OF SPECIES IN CALIFORNIA

BLACK BEAR

- **Legal hunting limit is ~1500 statewide per year.**
- **More than double that is estimated to be killed yearly, illegally, for their gall bladders and paws, which are exported to Asian markets as medicinals.**

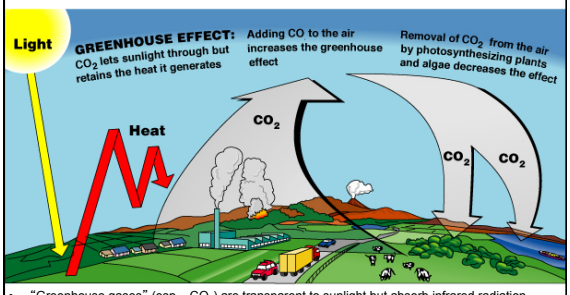
The Symbol of California

- A mammal hunted to extinction by 1922
  - **California grizzly ("golden bear")**

Case Study: ***Analysis of Grizzly Bear Populations***

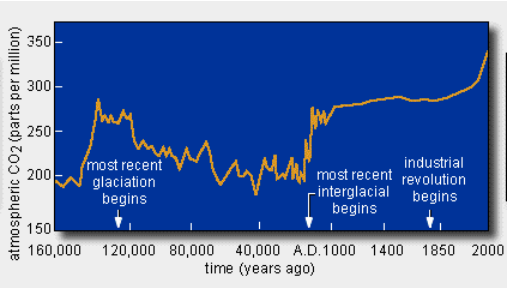
- One of the first population viability analyses was conducted as part of a long-term study of grizzly bears in Yellowstone National Park
  - The Yellowstone grizzly population has low genetic variability compared with other grizzly populations
- It is estimated that a population of 100 bears would have a 95% chance of surviving about 200 years
- This grizzly population is about 400, but the N_e is about 100
  - Introducing individuals from other populations would increase the numbers and genetic variation

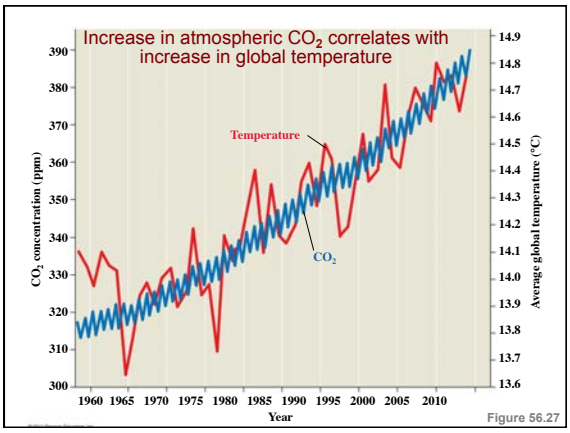
Global habitat impact: the Greenhouse effect



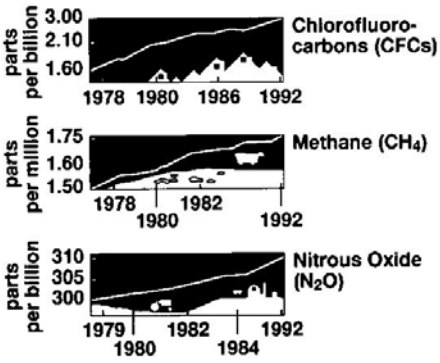
- "Greenhouse gases" (esp.., CO_2) are transparent to sunlight but absorb infrared radiation trap heat within atmosphere

Green house effect: excess CO_2 in atmosphere

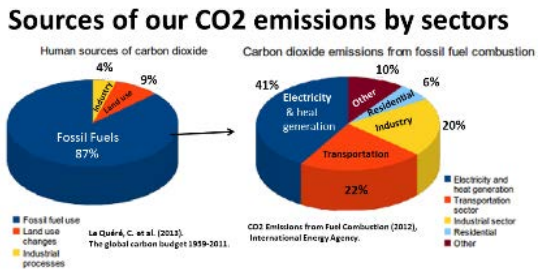


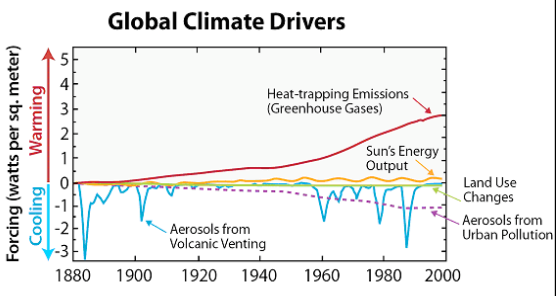


Other Greenhouse Gases

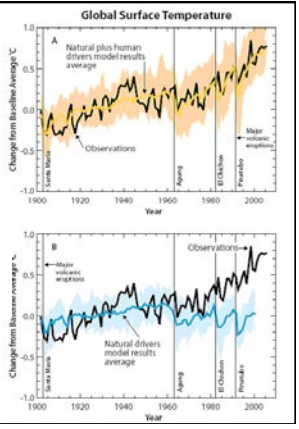


Sources of CO_2 Emissions



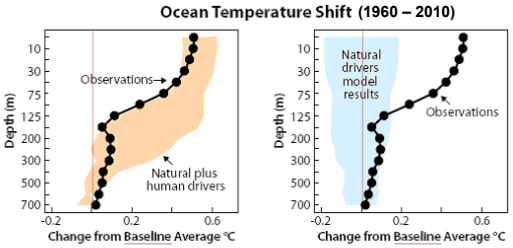


Ecological Modeling the combined effects of climate drivers



The model output that includes both natural and human-induced climate drivers (orange shading) gives a better match with observed temperature response (black line) than model output that includes only natural climate drivers (blue shading). Each solid color line within each shaded region is the average of all the model results. Adapted from IPCC AR4 2007.

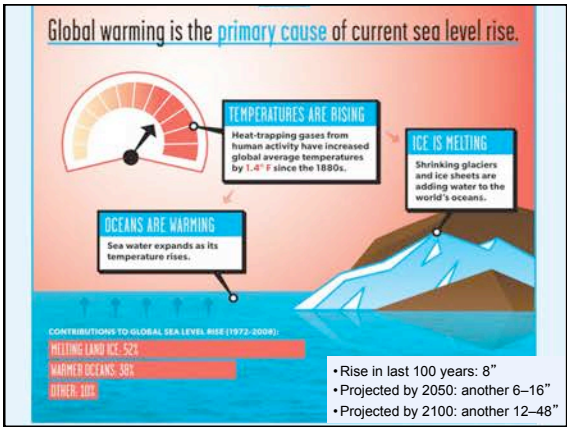
Global warming & the ocean's thermal budget



Observed temperature shift for the ocean averaged at each depth (black circles) compared to results from models with natural plus human drivers (orange shading) is a better match than natural drivers models (blue shading). Adapted from IPCC AR4 2007.

Probable consequences of the greenhouse effect

- Melt polar ice caps, raise sea levels
  - Flood heavily populated coastal areas
- Alterations in global precipitation patterns
  - Desertification of agricultural areas
  - Deplete snow-pack water reserves
- Shift of great ocean current patterns
  - Decreased heat transfer away from tropics
  - More extreme climates between equator and poles
- Major changes in habitats leading to population shifts and loss of biodiversity



IMPACTS OF GLOBAL WARMING

- Change in sea level
  - Coastlines
  - Islands

IMPACTS OF GLOBAL WARMING

- Geographical shifts
  - Animals
  - Plants
- Sociological & political shifts
  - Food supply

Climate Change Vulnerability Assessments (CCVA)

- Efforts to analyze and predict what species are most impacted by climate change
- Δ habitat availability/quality and/or physiological stress

- Review of 2000 animal spp already listed as endangered or threatened:
  - 47% of non-volant land mammals & 23% of bird spp already impacted and face possible extinction *

*Species' traits influenced their response to recent climate change *Nature Climate Change* 7:205–208 (2017)

Climate Change Vulnerability Assessments (CCVA)

- **Exposure**
- The magnitude and type of environmental changes that a population is likely to experience under future climate scenarios.
- The most difficult parameter to predict

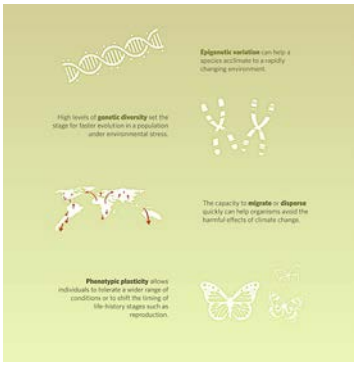
Identifying Future Victims of Climate Change, *The Scientist* Jul 1, 2018

Climate Change Vulnerability Assessments (CCVA)

- **Sensitivity**
- A measure of how likely a species is to experience negative effects of climate change.

Climate Change Vulnerability Assessments (CCVA)

- **Adaptive Capacity**
- The potential for species and populations to temporarily escape the negative effects of climate change via natural selection or individual plasticity.



Deterioration of the Ozone Layer

- Ozone (O_3) layer — region ~20km up in atmosphere
- Absorbs much of the UV radiation from the sun
- Chlorofluorocarbons (CFCs) from industrial processes (e.g., refrigerants, propellants, insulation) rise to upper atmosphere and degrade to release chlorine
- Chlorine catalyzes degradation of O_3 to O_2 → decreases thickness of ozone layer

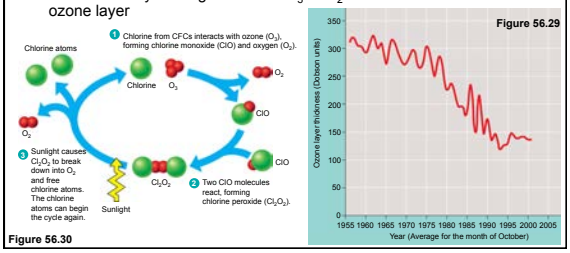
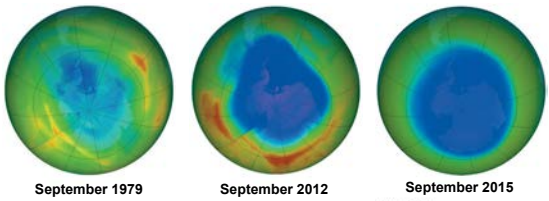


Figure 56.30

Deterioration of the Ozone Layer

- Upper atmospheric winds concentrate CFCs toward poles
- Thinning of ozone layer most severe over arctic/antarctic
  - **"Ozone hole"**
- But even temperate latitudes have thinned 2–10% over past 20 years



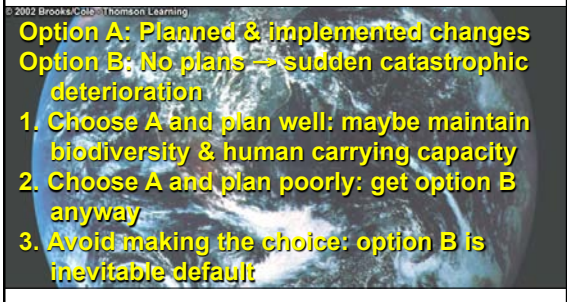
September 1979 **September 2012** **September 2015**

Deterioration of the Ozone Layer

Increased UV radiation exposure:

- Increased rate of skin burn and melanoma
  - "Tan today … cancer tomorrow"
- Increased rate of cataracts
  - Argentinan cattle
- Possible destruction or inhibition of phytoplankton
  - Potential major disruption of global food webs and maybe even weather

Human societies are changing the planet's biosphere!



Ecology and Environmentalism

- **Ecology** — Provides the scientific understanding underlying environmental issues
- **Sustainable Development**
  - Long-term prosperity of both humans and ecosystems
  - Commitment to protect and preserve biodiversity
  - "Stewards of the land"
    - Decisions that benefit future generations

Figure 50.1

CONSERVATION STRATEGIES

- **Research and more research**
- **Sound bio-reserve design**
- **Corridors**
- **Re-introduction**
- **Captive breeding**
- **Conservation of foundation species**
- **Conservation of umbrella species**
- **Habitat restoration**
- **Education and more education**

RESEARCH!

In genetics, forensics, habitat quality assessment, home range analysis, systematics, rapid assessment in critical areas, cultural anthropology . . . All needed! Quick!

Understanding community dynamics

- allows biomanipulation to restore polluted ecosystem

Restoration of Lake Vesijarvi, Finland

- Cultural eutrophication (sewage) allowed overgrowth of noxious alga and cyanobacteria
- 1. Sewage treatment alone did not restore lake ecosystem

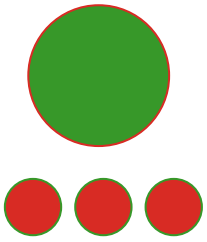
Food Chain	Polluted State	Restored State
Fish	Abundant	Rare
↑		
Zooplankton	Rare	Abundant
↑		
Algae	Abundant	Rare

- 2. ⇓ the fish population ⇒ allowed ⇑ zooplankton population
- ⇒ abundant zooplankton reduced alga & cyano populations

BIO-RESERVE DESIGN

Large reserves are better than small.

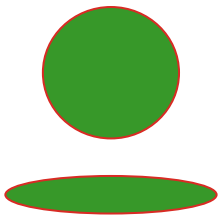
- **large species**
- **large home range**
- **higher diversity**
- **less edge effect**



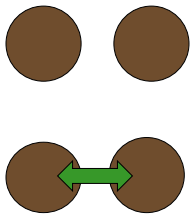
BIO-RESERVE DESIGN

Large, circular or square reserves are better than long, strip-like reserves.

- **less edge effect**
- **less wind damage**
- **fewer opportunistic predators**



BIO-RESERVE DESIGN



Corridors between reserves help

- **maintain population contacts.**
- **allow dispersal of young.**
- **aid migrating species.**

Movement corridors to connect habitat patches

- **Movement corridors** promote dispersal, help sustain populations
- Esp. to maintain contact from source habitats
- Multiple patches may be better than one big area
  - For *some* species
  - *Only* if connections are sufficient

Underpass serves as a movement corridor

REINTRODUCTION

Populations of recovered species are brought back to their native habitat (assuming it still exists).

Examples: tule elk, pronghorn, condor in CA.

(Right, tule elk photo by Stasia McGehee, De Anza ES 85A class)

CAPTIVE BREEDING

Animals/plants are held in captivity until enough are available for reintroduction.

Examples: black-footed ferret, Przewalski horse, Pere David's deer, Arabian oryx.

PERE DAVID'S DEER

- **Last individuals in native China were eaten by troops during the Boxer Rebellion, early 1900's.**
- **Fortunately, small captive herds existed in England, and provided the start of a new population.**

PRZEWALSKI'S HORSE (TAKHI)

- **Declared extinct in native Mongolia in 1960's**
- **Again, captive herds in the US, England & Europe became the nucleus of new groups.**
- **Horse reintroduced to Mongolia in mid-1990's.**

THE ARABIAN ORYX

- Last wild group run down and shot for "fun" by Saudi soldiers in 1970's; antelope was extinct in the wild.
- Captive-bred herds since reintroduced into former range in Saudi Arabia & Oman.

FOUNDATION SPECIES CONSERVATION

Foundation species help determine the make-up and integrity of ecosystems; without them, ecosystems become less stable.

- Keystone predators
- Ecosystem engineers
- Critical pollinators

Figure 53.18

Figure 55.8

FOUNDATION SPECIES

- Some foundation species act as facilitators that have positive effects on the survival and reproduction of many of the other species in the community
- Black rush (*Juncus*): shade reduces evaporation; snorkel-roots oxygenate sediment

Salt marsh with *Juncus* (foreground)

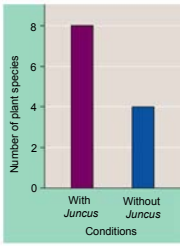


Figure 53.19

UMBRELLA SPECIES CONSERVATION

Grizzly bear

Umbrella species tend to be big, charismatic species with big ranges. Protect them, and you protect everything else by default.

UMBRELLA SPECIES

Because the **Endangered Species Act** (as it stands currently) mandates protection of habitat in addition to the species itself, umbrella species help protect many others.

Restoration: Habitat Recovery

- **Bioremediation**
  - Lichens to remove heavy metals
  - Bacteria or fungi to detoxify oil spills
- **Ecosystem Augmentation**
  - Replenish factors limiting recovery
  - Legumes in tropical soils

Metal-concentrating lichens