Millennium Ecosystem Assessment
http://www.millenniumassessment.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.millenniumassessment.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
- Regional & global impacts
  - Loss of biodiversity
  - Loss of overall life support

Real and potential human insults to the integrity of the biosphere
1. Disrupted biogeochemical cycles
2. Global contamination (pollution)
3. Lost biodiversity [HIPPO]
4. Climate change
5. Destruction of the ozone layer
6. (Nuclear winter)

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 CO₂; depleted fossil pools
- Soils:
  - Erosion; nutrient depletion; fire suppression
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

Environmental Toxicology

- Persistent toxins
  - Fat soluble or skeletal
  - Bioaccumulate in individuals
  - Biomagnify in food chains

- Endocrine disruptors
  - Interfere or imitate hormone action
  - Perturb reproduction and/or development

- Mutagens
  - Damage DNA
  - Carcinogenic / Teratogenic

Carbon Monoxide Levels as an Indicator of Air Pollution

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- Enzyme induction
  - Glutathione S-Transferase
  - Mixed Function Oxidases
  - Hydrolases

- DNA repair mechanisms
  - Glutathione S-Transferase
  - Mixed Function Oxidases
  - Hydrolases

- Biochemical integrity
  - Key enzymes

- Ecosystem effect
  - Physiological, Behavior
  - Chromosome damage
  - Lesions, Necrosis
  - Tumors
  - Teratogenic effects
  - Behavior, Mortality

- Community structure
  - Diversity
  - Energy transfer
  - Stability
  - Succession

- Chemical parameters
  - Stress proteins
  - Metabolic indicators
    - Acetylcholinesterase inhibition
    - Adenyl energy charge
    - Metallothionen production
    - Immuno suppression
  - Population density
    - Productivity
    - Mating success
    - Fecundity
  - Genetic alterations
  - Competitive alterations

- Population density
  - Productivity
  - Mating success
  - Fecundity

- Genetic alterations
  - Competitive alterations

- Competitive alterations
  - Biotransformation

- Site of action
  - Biotransformation

- Biochemical integrity
  - Key enzymes

- Introduction of xenobiotic
Persistent Environmental Toxins

<table>
<thead>
<tr>
<th>Toxin</th>
<th>Sources / comments</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCBs (polychlorinated</td>
<td>Banned industrial chemicals, still persists after decades. Cancer, impaired fetal brain development</td>
<td></td>
</tr>
<tr>
<td>biphenyls)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td>60% of herbicides, 30% of fungicides, 30% of insecticides known to be carcinogenic. Cancer, Parkinson's disease, miscarriage, nerve damage, birth defects, blocking nutrient absorption</td>
<td></td>
</tr>
<tr>
<td>Phthalates</td>
<td>Leach from soft plastic food storage containers, etc. Used to stabilize artificial fragrances. Endocrine disrupter</td>
<td></td>
</tr>
<tr>
<td>VOCs (Volatile Organic</td>
<td>Decompose to form ozone. Cancer, eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment</td>
<td></td>
</tr>
<tr>
<td>Compounds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dioxins</td>
<td>Form during combustion of organic wastes and fuels. Endocrine disrupter; carcinogenic, contact irritant, liver damage</td>
<td></td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>Industrial sources; mining; concentrated by over-irrigation practices. Cancer, developmental &amp; neurological disorders, cardiovascular damage, impaired blood cell production, block enzyme activity.</td>
<td></td>
</tr>
<tr>
<td>Chlorine &amp; Chloroform</td>
<td>Industrial processing. Leach from synthetic materials. Cancer, reproductive damage &amp; birth defects, neurological disorders, liver and kidney damage.</td>
<td></td>
</tr>
</tbody>
</table>

Measuring Ecotoxicity

- \( EC_{50} \): Effective Concentration: exposure producing a significant effect in 50% of the population
- \( LC_{50} \): Lethal Concentration: exposure causing mortality in 50% of the population

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.

Plants

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

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.
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.

**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

**Biodiversity Crisis**
- 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

**TOP (BOTTOM?) TWENTYFIVE BIODIVERSITY HOTSPOTS**

**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.

**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

**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.

**LOCAL EXAMPLES OF HABITAT LOSS & FRAGMENTATION**

- **SALT MARSH**
  - 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

**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

LOCAL EXAMPLES OF INVASIVE SPECIES

**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

**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

**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
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.

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

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 Ne is about 100
  - Introducing individuals from other populations would increase the numbers and genetic variation

Global habitat impact: the Greenhouse effect

Greenhouse effect: excess CO₂ in atmosphere

- "Greenhouse gases" (e.g., CO₂) are transparent to sunlight but absorb infrared radiation and trap heat within atmosphere
**Conservation Ecology**

**Sources of CO₂ Emissions**

- **Sources of our CO₂ emissions by sectors**
  - Human sources of carbon dioxide
  - Carbon dioxide emissions from fossil fuel combustion

**Other Greenhouse Gases**

- Chlorofluorocarbons (CFCs)
- Methane (CH₄)
- Nitrous Oxide (N₂O)

**Global Climate Drivers**

- Sun's Energy Output
- Land Use Changes
- Aerosols from Urban Pollution
- Aerosols from Volcanic Emission
- Heat-trapping Emissions (Greenhouse Gases)

**Ecological Modeling**

- The model output illustrates the combined effects of climate drivers on global surface temperature.

**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 (light 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

  - Rise in last 100 years: 8”
  - Projected by 2050: another 6–16”
  - Projected by 2100: another 12–48”

- 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
  - 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

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
Climate Change Vulnerability Assessments (CCVA)

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

- **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 (O₃) 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 O₃ to O₂ → decreases thickness of 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!

**Option A: Planned & implemented changes**
1. Choose A and plan well: maybe maintain biodiversity & human carrying capacity
2. Choose A and plan poorly: get option B anyway
3. Avoid making the choice: option B is inevitable default

**Option B: No plans → sudden catastrophic deterioration**
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

**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
- 2. Þ the fish population Þ allowed Þ zooplankton population
- Þ 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

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**

- 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

**UMBRELLA SPECIES**

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

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](image)