ENVIRONMENTAL BIOLOGY

BIO 105

LECTURE OUTLINES

DEPARTMENT OF BIOLOGY
WEST CAMPUS
PIMA COMMUNITY COLLEGE

Revised 2011

INTRODUCTION

What do we mean by "environmental problem"?
Why do we get ourselves into environmental problems?
How can we avoid or escape environmental problems?

<u>PERSPECTIVES:</u> the Me-Here-Now Syndrome

- Me >> Us >> Charismatic Megafauna >> All Life
- Personal >> Local >> Regional >> National >> Global
- Now >> Tomorrow >> Economic Future >> Ecological Future

<u>ATTITUDES:</u>

- **ROSY OPTIMISM:** What? There's a problem?
  Problem:
- **FRONTIER:** There's always more and it's all ours
  Problem:
- **TECHNOLOGICAL FIX:** We have or soon will have the ingenuity to solve any of our environmental problems
  Problem:
- **GLOOM-AND-DOOM:** The problems are beyond our abilities; there is nothing we can do, certainly not me, so why do anything?
  Problem:
- **SUSTAINABLE SOCIETY:** Use resources only at the rate they replenish themselves.
  Problem:

ENVIRONMENTAL PROBLEMS ARE A COMPLEX MIX OF FACTORS

- Ecological Interactions
- Political Interests
- Economic Interests
- Cultural Values
- Personal Worldview and Ethics

SOCIAL TRAPS: See notes.

SOCIAL TRAPS

SOURCE: Costanza, R. 1988. Social traps and environmental policy. Bioscience 37:407-412.

SOCIAL TRAPS DEFINED

Social Traps are situations in which a person, if they make their decision from a me-here-now perspective, makes the wrong decision in the long term/global context.

Costanza's definition: "A social trap is any situation in which the short-run, local reinforcements guiding individual behavior are inconsistent with the long-run, global best interest of the individual and society."

THE SOCIAL TRAPS

1. **Collective (Tragedy of the Commons)**: A person is thinking that their small effect won't matter, but it all adds up to a big problem when many people's small effects add together.
   Examples:

2. **Externality**: An action done by individual or group results in negative effects occurring to others (including other generations).
   Examples:

3. **Time Delay**: A person is thinking that their action today will result in a negative effect to themselves and/or society in the future, but they decide to do it anyway. The action only has to happen once to initiate the long term negative effect.
   Examples:

4. **Sliding Reinforcer**: A person is thinking that the first time they did the action, they benefited so they repeat the action. But each time they repeat the action, they get less and less benefit and more and more costs until the costs outweigh the benefit and the costs get steadily worse.
   Examples:

METHODS TO AVOID SOCIAL TRAPS

"All animals capable of choice can be trapped with the right bait. Intelligent ones can learn to avoid traps. Ingenious ones can even escape from traps. If we are to survive, we need to exercise our vaunted intelligence and ingenuity to see, avoid, and escape from the many complex traps we have laid for ourselves." -- Costanza (1987:412).

1. Education: Inform everyone of the social trap.
   Examples:
   Pros and Cons:

2. Rules and Regulations: Make laws.
   Examples:
   Pros and Cons:

3. Pay upfront: Take the long term effects and make the buyer of the product/service pay them up front so that a person making their decision on the here and now will make the right decision in the long term for society.
   Examples:
   Pros and Cons:

SCIENCE

Science Definition: Science is a way of learning about the natural world using a process designed to reduce the chance of being misled.

Products of Science

Hypotheses: tentative answers/explanations to questions.

Theories: broad-application, well-tested, widely accepted, explanations.

Process of Science

1. **Observations**: look at the world

2. **Question**: ask either a descriptive question (e.g., which side of the hill has more trees?) or causal question (e.g., why does the north side of the hill have more trees than the south side?)

3. **Literature Review**: Find out what is already known on the subject -- especially by using peer-reviewed, scientific journal articles – to help propose possible answers to the question.

4. **Multiple Hypotheses**: Propose as many alternative answers/explanations/ (hypotheses) as possible.

5. **Deductions:** for each hypothesis, state in advance the predicted results from the experiment if the hypothesis is correct.
   Often written in the form, "If hypothesis 1 is correct, and I conduct this experiment, then these specific results should happen."

6. **Conduct Experiment:** collect the actual results by carrying out the experiment(s).

7. **Tentative Conclusions**: by comparing the predicted results to the actual results state which hypotheses were refuted (predicted and actual results differ) and which hypotheses were supported (predicted and actual results match). Note: nothing in science is ever definite or proven, just supported or refuted by the tests conducted.

8. **Peer Review**: Submit report for publication to a peer-reviewed scientific journal. The journal editors give your paper to other experts in the scientific community to scrutinize.

Process of Science

Observation
▼
[Why?] **Causal Question**
▼
Literature Review
▼
[If…] **Proposed Explanations (Hypotheses)**
▼
[And…] **Experiment**

Thought experiment ▼ ▼ *Actual experiment*

[Then…] **Predicted Results** ► [And we observe…] **Actual Results**
▼
[Therefore…] **Tentative Conclusion**
▼
Peer Review

Example:

Why doesn't the light turn on? (Causal Question)

If… the bulb's filament is broken (Hypothesis)

And… the bulb is shaken and the sound recorded (Experiment)

Then… the bulb should rattle if shaken (Predicted Result)

And we observe… the bulb did rattle when shaken (Actual Result)

Therefore… the light did not turn on because the filament is broken (Tentative Conclusion)

Rules of Science (established to minimize the chance of being misled)

Maximize Sample Size: sample size should be as large as possible.

Representative Sample: sample must reflect population as a whole.

Controlled Experiments: to determine whether a particular factor causes a particular effect, a controlled study[1] must be conducted. A controlled study is one that uses at least two study groups. Both groups are alike (and are treated alike) in all ways. The experimental group then has one factor changed. Any differences between the two groups is likely to have been caused by the factor that was different between the two groups. Cause and effect relationships cannot be inferred from correlation alone; a controlled study must be conducted.

Correlation ≠ Causation: correlation between two variables does not necessarily indicate a causal relationship.

[1] If you want to know whether a particular factor (e.g., study time) has caused a particular effect (e.g., test grade), then a controlled study must be conducted. **CONTROLLED STUDIES** are based on comparing a control group (those that did not study for test) with an experimental group (those that did study). The control group and experimental group are treated identically (same amount of sleep, etc.) except for the one factor being tested for in the study (the independent variable; e.g., study time). The dependent variable (e.g., test grade) is the factor that changes as a result of what the scientist does to the independent variable and is what is measured by the scientist. Controlled studies usually change only one variable at a time so the scientist can pinpoint the factor causing the effect.

Limitations of Science

Cannot answer all questions. For example, questions about right and wrong are the realm of religion, ethics, philosophy, and politics.

Scientists can explain how to do something, technologists can make it so it is possible to do it, but politicians, etc. decide if we should do it.

Science, like all human endeavors is subject to human error, fraud, and conflict of interest.

PLATE TECTONICS

Major geological theory explaining Earth's topography.
Plate tectonics explains the movement of Earth's plates and the processes that occur at their boundary, and is critical to understanding mountain formation, volcanic eruptions, earthquakes, the locations of mineral resources, biogeochemical cycling, evolutionary history, and much more. The theory was proposed in the early 1960's and was based on earlier work on seafloor spreading and even earlier work by Alfred Wegner (Continental Drift).

A. Mechanism splitting crust into moving plates is **Convection Cells** in the mantle.

B. **<u>5 Types of Plate Boundaries</u>** based on ways plates move in relation to one another:

1. **<u>Divergent Plate Boundaries</u>**: plates move apart where convection cells upwell, producing non-explosive volcanic eruptions.
   -- Geological Features: Rifts, Ridges, and New Ocean Floor
   -- Examples:

2. **<u>Ocean-Continent Convergent Plate Boundaries</u>**: Oceanic crust collides and ***subducts*** beneath continental crust, causing explosive volcanic eruptions.
   Geological Features: Volcanic Mountain Chains and Trenches
   Examples:

3. **<u>Ocean-Ocean Convergent Plate Boundaries</u>**: Denser oceanic crust collides and ***subducts*** beneath less dense oceanic crust, causing explosive volcanic eruptions.
   Geological Features: Volcanic Island Arcs and Trenches
   Examples:

4. **<u>Continent-Continent Convergent Plate Boundaries</u>**: Continental crust collides with continental crust, causing both crusts to buckle and fold together.
   Geological Features: Upfolded Mountains
   Examples:

5. **<u>Transform Plate Boundaries</u>**: plates slide past each other.
   Geological Features: Strike-Slip Faults
   Examples:

C. **Hot Spots**: a plume of mantle material rises (under the interior of a plate), causing magma to extrude onto Earth's surface in the form of non-explosive volcanic activity. Plate movement over a mantle plume (stationary) causes a chain of volcanoes to form.

D. **Concepts**

a. Oceanic Crust (normal mantle material forced to surface by convection or mantle plumes – dark in color and dense) vs. Continental Crust (light weight materials in the mantle or from Earth's surface that comes to surface due to being less dense than rest of mantle – light in color and less dense).

b. Non-Explosive Volcanoes (normal mantle magma forced onto surface) vs. Explosive Volcanoes (light weight crustal material subducted into mantle comes up explosively due to less density).

CLIMATE

Climate is the average weather of an area over a long time period. Climate affects weathering of rocks and activities of microorganisms, thus development of soil, thus plant life, thus animal life. Living things in turn affect climate.

Most important factors: temperature (daily/seasonal) and precipitation (amt./distribution in time)

TEMPERATURE: affected by:

Latitude: sun's rays more direct when perpendicular (near equator) so hotter.

Elevation: cooler higher -- less atmospheric pressure causes air to expand, moving molecules farther apart, resulting in fewer molecular collisions, reducing temp.

Greenhouse Gas Content of Air: greenhouse gases (e.g., CO_2) and water vapor trap heat at Earth's surface (Greenhouse Effect), increasing average temperature and reducing temperature variability.

PRECIPITATION: affected by absolute humidity (moisture content of air) and movement of air

Relative Humidity (RH) is how much water is in the air as a percentage of how much water the air can maximally hold; in other words, the percentage air is saturated.

Hot air rises, as air rises it cools. Cool air holds less water than warm air; thus, as air cools by being raised up, its capacity to hold water decreases, its RH increases, and the chance of precipitation increases.

Conversely, as air warms by being forced downward, its capacity to hold water increases, its RH decreases, and chance of precipitation decreases.

Causes of Precipitation -- when air rises and cools by

i) convection (hot air rises)

ii) orographic (air pushed up side of mountain)

iii) frontal (warm air pushed up side of cold front)

Causes of Deserts -- when air has little moisture and/or when it is warmed by

i) Descending air in Hadley Cells (at 30 and 90 degrees N and S)

ii) Rainshadow Effect (air descends down from top of mountain range)

iii) Cold Ocean (little evaporation then air warms over land)

iv) Distance from Source of Water (little water left in air after long distance)

MISCELLANEOUS

Seasons are the result of Earth's tilt of 23.5 degrees, revolution around the sun, and changing angle of each hemisphere to the sun. When the northern hemisphere is tilted toward the sun, so that the sun's rays hit perpendicularly at 23.5 degrees north latitude, it is the summer solstice (June 21). Because the rays are more perpendicular, the sun's rays spread over less area (are more concentrated; more energy per square mile) and have to go through less atmosphere (so less energy is reflected and absorbed) so the temperatures are warmer. In the southern hemisphere on June 21, the hemisphere is tilted away from the sun so the rays are coming in at a low angle so it is their winter solstice.

Coriolis Effect deflects wind and moving water clockwise in N. Hemisphere and counter-clockwise in S. Hemisphere. Use Hadley Cell circulation and Coriolis Effect to determine **prevailing wind directions** and **ocean currents/temperatures**.

Biomes: major types of ecosystems on earth (e.g., tundra, boreal forest, temperate deciduous forest, grasslands, deserts, etc.) result from climate.

HOW EARTH WORKS: ENERGY FLOW AND MATTER CYCLING

Earth can be looked at as a huge system, made up of interdependent, interacting parts.

STRUCTURE AND FUNCTION OF BIOTIC COMPONENT OF EARTH

MAJOR COMPONENTS

- **Lithosphere**: land
- **Hydrosphere**: water
- **Atmosphere**: air
- **Organisms**: living things
  - [Biosphere: where organisms live]

LEVELS OF ORGANIZATION OF THE LIVING WORLD

Subatomic Particles >> Universe

- **<u>Organisms</u>**: are living things classified into species (1.5 m so far of perhaps 10-100 m)
- **<u>Population</u>**: group of individuals of same species occupying a given area at same time.
- **<u>Community</u>**: populations of all species occupying a particular place.
- **<u>Ecosystem</u>**: community(s) interacting with one another and with physical environment.
- **<u>Biomes</u>**: major categories of ecosystems; tundra, boreal forest, temperate deciduous forest, grasslands, deserts, etc.

Ecology is the scientific study of ecosystem structure and function (including interactions among organisms and between organisms and their physical environment)

<u>ECOSYSTEM STRUCTURE</u>

1. **Energy Source**: usually sunlight
2. **Physical Environment**: non-living materials (e.g., air, water, minerals, etc.)
3. **Producers**: make own food
4. **Consumers**: eat other living things (primary, secondary, etc.)
5. **Decomposers**: eat waste matter and dead living things

<u>ECOSYSTEM FUNCTION</u>

1. **One-Way Flow of Energy**: from high quality solar energy, through materials and living things, and eventually back into space as low quality heat
2. **Matter Cycling** Biogeochemical Cycles (movement of nutrients from physical environment to organisms, and back).

ENERGY FLOW (energy drives the system, so it is important to understand)

Definitions:

- -- energy: the ability to do work
- -- energy quality: measure of ability to do work
  - -- high: organized, concentrated, great ability to do useful work. Eg. electricity
  - -- low: disorganized or dilute, low ability to do useful work. Eg. heat less than $100^{o}C$

A. FIRST AND SECOND LAWS OF ENERGY

1. First Law: Energy is neither created nor destroyed, just transformed from one form to another.

2. Second Law: Energy quality is degraded with each conversion/use of the energy.
   - -- *Energy Quality Tax*
   - -- Cannot recycle or reuse high quality energy.

B. ENERGY FLOW IN ECOSYSTEMS

Major source of all energy is sun

Producers: capture solar energy by converting it to chemical energy in the form of organic compounds (used for structure and energy).

PHOTOSYNTHESIS: jam together carbon dioxide (CO_2) and water (H_2O) to make carbohydrates [sugars which are $(CH_2O)_x$] and release oxygen (O_2).

$6CO_2 + 6H_2O$ + solar energy >> $C_6H_{12}O_6 + 6O_2$

CELLULAR RESPIRATION: releases energy, water, and CO_2 by reversing what happens in photosynthesis.

$C_6H_{12}O_6 + 6O_2$ >> $6CO_2 + 6H_2O$ +chemical energy

Consumers: acquire energy from eating producers and/or other consumers. Herbivores (primary consumers), carnivores (secondary, tertiary, etc. consumers), and omnivores. Also scavengers. *Cellular Respiration* releases energy.

Decomposers: feed on dead organic matter and break down to constituent components. *Cellular Respiration* releases energy.

Concepts:

Food Chain: A series of organisms, each eating or decomposing the preceding one. A channel for the one-way flow of energy (and the recycling of materials).

Trophic Level: all organisms that share the same general type of food. Producers, consumers (primary, secondary, etc.), and decomposers.

Food Web: A tracing of the movement of all energy (and matter) passing through an ecosystem, including all interconnected food chains.

Pyramid of Energy: due to "energy quality tax" imposed by 2nd law of energy (at each transfer between trophic levels in a food chain or web, work is done, low quality heat is given off, thus the availability of high-quality energy to the next trophic level is reduced). Only 2-30% energy transfer occurs between successive trophic levels, depending on species and ecosystem involved -- average of about 10%. Pyramid of energy may also lead to Pyramids of Biomass and Numbers. Thus more people supported by plants than by animal meat.

Net Primary Productivity: rate at which plants produce chemical energy (photosynthesis) minus rate at which plants use chemical energy (respiration). The "profits created by plants and the income of animals." Compare ecosystems. Compare between per unit area and total.

Net Ecosystem Productivity (NEP)
= NPP - (heterotrophic respiration of litter, woody debris and soil organic matter)

Net Biome Productivity
= NEP - (harvest wood losses and fire)

MATTER RECYCLING IN ECOSYSTEMS

Biogeochemical Cycles: movement of nutrients from environment to organisms and back again.

Law of Conservation of Matter: matter is neither created nor destroyed, just rearranged. There is no away! Earth essentially has all the matter it will ever have.

CHNOPS: carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur are the major elements making up living things, like you ($C_{1480}H_{2960}N_{16}O_{1480}P_{1.8}S$)

A. Reservoirs for biogeochemicals to reside
   1. Lithosphere
   2. Hydrosphere
   3. Atmosphere
   4. Organisms

What does this mean? Breathe out into your hand. The carbon in that CO_2 used to be part of you, you obtained it from eating that cereal this morning, the wheat plant obtained it from the atmosphere, where it may have come from a volcano (or an exhaust pipe), from a rock, etc.

B. Types of biogeochemical cycles
   1. Hydrological (water)

   2. Carbon
      - Atmosphere
         - in by: respiration, burning fossil fuels and biomass, volcanoes
         - out by photosynthesis, dissolving in ocean
      - organisms:
         - in by photosynthesis, feeding
         - out by respiration, burning, decomposition, lack of decomposition
      - hydrosphere:
         - in by dissolving
         - out by uptake by organisms
      - lithosphere:
         - in by lack of decomposition (formation of ocean sediment and fossil fuels)
         - out by burning fossil fuels, weathering of sediments, volcanoes

3. Nitrogen (nitrogen fixation and denitrification)

4. Phosporous (no atmospheric phase)

Rate of movement: depends on whether there is an atmospheric phase and presence and activity level of organisms

C. Ecosystem Services: climate control, regulation of freshwater, generation and maintenance of soils, waste removal and nutrient recycling, pest and disease control, pollination, maintenance of genetic library, etc.

HOW EARTH WORKS: POPULATION & COMMUNITY DYNAMICS

SPECIES: one or more populations whose members actually or potentially <u>interbreed</u> under natural conditions and are <u>reproductively isolated</u> from other such groups.

HABITAT

An organism's place or type of place it lives and thrives.

Includes food, water, cover, and space.

Microhabitat: the habitat the organisms are really using -- has its own climate regime.

NICHE

What the organism <u>does</u> in its habitat. Includes all the physical and biological factors and interactions of the organism.

<u>Specialists vs. Generalists</u>

Plants or animals with narrow tolerance ranges and/or specific dietary constraints, etc. (i.e. specialized niches) are said to be specialists and are prone to extinction relative to generalists with a generalized niche (variety of habitats/foods/etc.) that are very adaptable and less prone to extinction.

Compare niche to occupation (janitor vs. mayor) to assess range, abundance, & habitat diversity

Fundamental vs. Realized Niches

What determines whether a species will occur at any given place? Three things: it must be able to <u>get there</u> (evolved or immigrated), <u>survive there</u> (within tolerance limits and relationships with other organisms) and <u>reproduce there</u>.

GETTING THERE

1. EVOLUTION (coming later)
2. IMMIGRATION
   - A. Expansion of Range
   - B. Storm or Floating Debris
   - C. Uniting of Land Masses
3. INTRODUCTION
   - A. Native Species
   - B. Endemic Species
   - C. Introduced/Exotic/Alien Species

SURVIVING THERE

PHYSICAL ENVIRONMENT

Range of Tolerance

The reason organisms are found in particular places and not everywhere is because individuals and species have a range of tolerance to variations in physical factors (e.g. temperature, precipitation, salinity, nutrient levels, etc.).

Acclimation: change in tolerance to certain physical factors – physiological changes within an individual to slowly changing new conditions (not adaptation).

Limiting Factors

All it takes is a single factor to be outside of the range of tolerance (above or below) to limit population growth -- this factor is called a limiting factor.

Examples: saguaro distribution; over-watered house plant

BIOLOGICAL ENVIRONMENT: TYPES OF INTERRELATIONSHIPS

Mutualism: interaction benefits both species.

Competition: reduces reproductive success of both species or individuals

Predation/Parasitism: Predators feed on the prey after quickly killing it. Parasites feed on the host, but the hosts either are not killed or are killed slowly.

Commensalism: one benefits the other is unaffected.

REPRODUCING THERE

ECOSYSTEMS: WHAT CAN HAPPEN TO THEM

RESPONSES OF LIVING SYSTEMS TO ENVIRONMENTAL STRESSES

Homeostasis and Information Feedback

- Homeostasis: a dynamic steady state
- Feedback loop: the return of output to a system as input. A circuit of sensing, evaluating, and reacting to changes in environmental conditions.
  - Negative: Says "no" to a change away from homeostasis. Counteracts change. Keeps things “the same”.
  - Positive: Says "yes" to a change away from homeostasis. Increases change. Vicious Cycle.
- Time delays: time lag between stimulus and the system's corrective action by negative feedback. Relates to time delay social traps (cigarette smoking, pollutant effects, ozone depletion, deforestation, etc.)

<u>Types and Effects of Environmental Stresses</u>:

- Natural vs. Human-Caused
- Organism, Population, Community/Ecosystem Level Effects

POPULATION RESPONSES TO STRESS (<u>3 major responses</u>)

1. migrate out of area (easier for some than others)
2. adapt through natural selection (depends on genetic variability and rate and degree of environmental change)
3. become extinct

COMMUNITY-ECOSYSTEM RESPONSES TO STRESS

- Difficult to understand due to difficulty of performing controlled experiments and much greater complexity in field then in lab conditions; therefore, difficult to make broad statements.

ECOSYSTEM STABILITY

Many human activities (e.g. mining, oil extraction and spills, etc.) impact ecosystems. Being able to predict the short-term and long-term effects of these impacts on the environment is important. The two elements of ecosystem stability are ecosystem persistence and ecosystem resilience.

Ecosystem Persistence: ability to resist being disturbed or altered

Ecosystem Resilience: ability to restore itself close to original condition after disturbance

ECOLOGICAL SUCCESSION

Definition: Somewhat directional, somewhat predictable change in ecosystem structure and function following a disturbance.

Early successional stages >> Late successional stages

Different wildlife species prefer different stages and many require a mosaic of stages to meet their diverse needs.

EVOLUTION

BASIC GENETICS

Genetic Information is contained in the *sequence* of nucleotides (A, T, C, and G) along the DNA molecule. Each sequence of 3 nucleotides codes for a specific amino acid. A chain of amino acids makes a protein. Proteins are the basis of all our traits. Genes are the specific sections of DNA that code for proteins.

Allele: one of the alternative forms of a gene.

Gene Pool: the sum of all alleles carried by members of a population; the total genetic variability present in any population.

By various mechanisms, population gene pools change over time (genes are added or lost, or the proportions of genes change in the population), and this is called biological evolution.

BIOLOGICAL EVOLUTION: genetic change over time in a population

Mechanisms of evolution:

Mutation (must be heritable)

Migration (Gene Flow)

Chance (Genetic Drift)

Natural Selection (see flow chart)

NATURAL SELECTION (see flow chart)

Definition of Natural Selection: the process whereby traits increase in future generations if they are in reproductively successful individuals and decrease if they are in reproductively unsuccessful individuals.

Related Concepts:

- Adaptations are genetic traits that confer reproductive success in the particular environment in which the population lives.

- Aspects of the environment (physical or biological) that affect reproductive success are referred to as Selection Pressures.

Applications:

- Explains much of the current form, function, and behavior of organisms.
- Explains genetic resistance: eg. to disease, antibiotics, pesticides, pollution, etc.
- Allows prediction of effects of environmental change on populations/species: whether a population/species is able to adapt to a changing environment depends on amount of genetic variability (related to population size, mode of reproduction, generation time and number of offspring per generation) and the strength, direction, and rate of environmental change.

Major Points of Confusion:

- Environmental change may cause a "need" for a new gene but cannot cause the new gene to be produced. Only already existing genes may be selected from.
- Only characteristics genetically determined (thus potentially passed to offspring) undergo the process of natural selection.
- When the phrase "survival of the fittest" was coined, fitness meant relative reproductive success, and survival referred to traits.

NATURAL SELECTION FLOW CHART

Mutation	**Recombination**
-- new genes	-- mix existing genes

▼ ▼

Genetic Diversity
-- gene pool

▼ ▼

Environmental Selection Pressures
-- Physical and Biological

▼ ▼

Differential Survival ►►►► **Differential Reproduction**

▼ ▼

Back through Mutation/Recombination to the next generation's gene pool

TYPES OF EVOLUTION

1. **DIVERGENT EVOLUTION**: different populations within a species become genetically different due to experiencing different selection pressures.
   SPECIATION will result if
   REPRODUCTIVE ISOLATION occurs

2. **CONVERGENT EVOLUTION**: very different species come to have similar characteristics (physical/behavioral) due to experiencing similar selection pressures.

3. **COEVOLUTION**: interacting species act as selection pressures on each other.

WATER RESOURCES AND POLLUTION

INTRODUCTION

You are 65% water and can only go a few days without it.

Water is potentially renewable; must be used at a sustainable rate and not polluted.

Water shortage is and will continue to be a serious environmental problem.

HYDROLOGY

<u>Water Distribution</u>

70% of Earth's surface is water, but 97% is salt water

2.997% is locked up in ice caps and glaciers or is buried uneconomically deep.

0.003% is usable fresh water

<u>Hydrological Cycle</u>

LOCAL CYCLE: What happens to water that falls on land?

- 2/3 Evapotranspires
- 1/3 Runoff
- 3% Seeps into Groundwater

GLOBAL CYCLE: see Diagram

WATER USE BY SECTOR

World: 70% agric., 25% industry, 10% public/municipal

U.S.: 49% industry, 41% agric., 10% public/municipal

Note: differs between east and west; Arizona: 89% used by Agric.

Note: only about 1/3 of irrigation water is taken up by crops.

Residential: 38% toilet, 22% shower, 15% tub/sink, 15% laundry, 10% kitchen

SOURCES OF WATER IN US

Surface (rivers and lakes): 75%

Groundwater: 25% avg., but much higher in dry areas;

-- 50% of drinking water, 40% of agric. water.

-- 1/2 of all Americans and 95% of rural Americans depend on groundwater.

GROUNDWATER (water within the pores of underground clay, silt, sand, gravel, and rock)

1. ***zone of aeration***: upper soil layer that hold both air and water.

2. ***zone of saturation***: lower soil layers where all available pores are filled with water.
   -- ***water table***: top of zone of saturation.

3. ***aquifers***: (pronounced a-qui-fur): groundwater that can yield an economically significant amount of water.

4. ***recharge area***: where water is added. Want to protect against pollution and compaction, etc.

5. ***discharge area***; where water comes out (wells, springs, lakes, streams, oceans, geysers)

PROBLEMS WITH OVERPUMPING GROUNDWATER

Recharge rates are slow (fossil water): when discharge > recharge = mining water
- -- Recharge slowed due to urban development: cement over recharge areas
- -- Recharge rate in Tucson area is estimated at 45,000 acre-feet per year (afy)

Water table under Tucson has been dropping an average of 1 meter per year since the 1940s. It is currently 300-400 feet below the surface.

Problems:
1. **Higher Costs** to dig deeper wells and pump water farther up
2. **Lower Quality** of water
3. **Loss of Habitat** (as streams, springs, etc. dry up)
4. **Subsidence:** settling of surface; Tucson basin ground surface is dropping an average one inch per 1 meter drop in water table. Rates of subsidence in the Tucson Basin range from 1/2 inch to 2 inches per year. Inelastic subsidence may be occurring. Problems with subsidence include structural damage (buildings, roads, sewer lines, etc.).
5. **Saltwater Intrusion:** saltwater being sucked into aquifer. Problem is salty water pumped up where once there was fresh water.

LAWS

Prior Appropriation: the first user of water from a stream establishes a legal right for continued use of the amount withdrawn. May also have use it or lose it. Ramsey Canyon.
Used in much of the West.

Riparian Rights: anyone whose land adjoins a flowing stream has the right to use water from the stream as long as some is left for downstream landowners.
Used in most of the East

Combination of above: in other states such as CA, TX, etc.

Water allocation between states is determined by interstate compacts and court decrees.

GETTING MORE WATER AT A GIVEN LOCATION

1. Groundwater: most in west is fossil water; one-time use
2. Cloud Seeding: only a solution where you stand; stealing
3. Dams: evaporation, leakage, siltation, loss of river; 3X more water evaporates from Lake Mead than Nevada's allocation of water from the Colorado River.
4. Water Diversions:
   CAP: Central Arizona Project
   NAWAPA: N. Amer. Water and Power Alliance (from Canada)
5. Desalination
6. Tow Icebergs
7. Conservation is Key: Biggest gains in agriculture.

WATER POLLUTION

Water Pollution: any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses.
Oil, pesticides, other chemicals, municipal waste water, heat, etc.

Point vs Nonpoint Sources

Point Source: discrete and identifiable sources of pollution; sources from which pollution is discharged from specific location, eg. drain pipes, ditches, sewer outfalls. Relatively easy to monitor and enforce regs.

Nonpoint Source: scattered or diffuse, having no specific location where they are discharged.

Major Types and Effects of Water Pollutants

A. Health

B. Ecosystem Disruption

SURFACE POLLUTION

Definitions

Biological Oxygen Demand (BOD): standardized test -- amount of dissolved O utilized by aquatic microorganisms over a five day period.

Dissolved Oxygen (DO): measure of oxygen dissolved in water. Depends on factors other than pollution (e.g. temp and aeration), but it is usually more directly related to whether aquatic organisms survive than BOD.

WASTE WATER TREATMENT

Inadequate waste water treatment is responsible for 80% of human diseases.

Types (Stages) of Wastewater Treatment:

Primary: mechanical process using screens to filter out large solids, settling of other materials and sludge. About half of the suspended, organic solids remain.

Secondary: biological process using aerobic bacteria that removes degradable, oxygen-demanding organic wastes. Trickling filter bed with microorganisms, aeration tank with microorganisms. Product is sludge and water.. Then water usually treated with chlorine to kill harmful bacteria. Still left with 3-5% of oxygen-demanding wastes, 3% of suspended solids, 50% of nitrogen (nitrates), 70% of phosphorous (phosphates), and 30% of most toxic metal compounds and synthetic organic chemicals. Virtually no radioactive wastes or persistent organic chemicals such as pesticides are removed.

Tertiary: series of specialized chemical and physical processes that remove plant nutrients, esp nitrates and phosphates. Can also treat specific chemicals.

HUMAN POPULATION DYNAMICS

POPULATION CHARACTERISTICS

1. **Size**: # of individuals (population)

2. **Density**: # of individuals/unit area

3. **Dispersion or Distribution**: e.g. urbanization

4. **Age Structure**: age and sex proportions in the population

TYPES OF CHANGE IN POPULATION SIZE

A. **Linear**: a quantity increases by some fixed amount during each unit of time.

B. **Exponential**: a quantity increases by a fixed percentage of the whole during each time unit.

J Curve

Biotic Potential of Species: maximum possible growth rate; no limitations.

"A major shortcoming of the human race is our failure to understand the implications of exponential growth." Miller (1992:5)

Rule of 70 to determine **Doubling Time**: The higher the percentage increase, the less time it takes for the population to double and the faster the population increases.

70/percentage growth rate = time it takes for pop to double (in same units as growth rate is given.

C. **Logistic**: as the pop increases beyond a certain point, the rate of growth of the pop progressively slows to 0.

S Curve; stabilizing; requires <u>negative feedback loop</u>

Carrying Capacity: maximum number of individuals an area can support forever.

- -- Law: Thou shalt not transgress the carrying capacity, for long. Overshooting leads to Crash and effect of overshooting may be a lowering of carrying capacity.
- -- Should our goal be to bring our human population to carrying capacity and keep it there?

EXPONENTIAL GROWTH OF HUMAN POPULATION

Stop and imagine for 8 seconds: the human pop on earth increased by 24; 36 people were born and 12 people died. Nine tenths (22) of the children born were born in LDCs.

During this class 32,000 people will have been added to the world's population (48,000 born and 16,000 died). Every minute 178 people are added to the global population.

CURRENT HUMAN POPULATION

http://www.census.gov/main/www/popclock.html

How much is a billion? 1000 seconds = ?; 1 million seconds = ?; 1 billion seconds = ?

1 trillion seconds = ?

Rule of 70 for determining doubling time:

70/Percent annual change in population = Doubling Time

70/2 = 35 years for population to double

Trend in Population is exponential

World Population	**When Reached?**	**How Long Did It Take?**
1 Billion	about 1800	all of human history
2 Billion	1930	130 years
3 Billion	1960	30 years
4 Billion	1974	14 years
5 Billion	1987	13 years
6 Billion	1999	12 years

Why the sudden increase?

Decline in <u>death rates</u> compared to birth rates.

Death rates declined due to improved agricultural productivity, food distribution, nutrition, sanitation, medicine.

More Developed Countries (MDCs) versus **Lesser Developed Countries** (LDCs)

MDCs include Europe, N. America, Former USSR, Japan, Australia, New Zealand

Differences in Population Demography

MDCs have 22% of population, 0.5% annual growth rate, 10% of new babies born, have 80% of wealth, and use 80% of mineral and energy resources.

LDCs have 78% of population, 2.1% annual growth rate, 90% of new babies born, 20% of wealth, and use 20% of mineral and energy resources.

U.S. = 288 million people growing at rate of 1.0% annually (70.0 yrs)

Mexico = 103 million people growing at rate of 1.8% annually (38.9 yrs)

Updates/Others: http://www.census.gov/ipc/www/idbsum.html

People Overpopulation vs Consumption Overpopulation

MAJOR FACTORS AFFECTING POPULATION SIZE

FACTORS AFFECTING BIRTH AND DEATH RATES

A.DEFINITIONS

1. Crude Birth and Death Rates: on a per 1000 population basis

2. Percent Annual Rate of Population Change: (births + immigration) - (deaths + emigration)/1000 persons X 100

3. Doubling Time: 70/Percent Annual Rate of Population Change

4. Total Fertility Rate (TFR)
   a. estimate of ave. # of children a woman will have in her lifetime (15-44).
   b. 2004: world was 2.8, 1.6 in MDCs and 3.1 in LDCs. Range 1.2 Poland – 8.0 Niger
   c. 2004: U.S. was 2.0; Mexico = 2.8
   source: http://www.prb.org/

5. Replacement-Level Fertility Rate
   a. # kids a couple must have to replace themselves
   b. 2.1 in MDCs to 2.5 in some LDCs

B. MAJOR FACTOR AFFECTING BIRTH RATES

1. education and affluence
2. importance of children in family labor force
   -- urbanization
3. high costs of raising and educating children
4. educational and employment opportunities for women
5. infant mortality rates
6. availability of retirement systems
7. availability of reliable methods of birth control
8. religious and cultural norms

C. MAJOR FACTORS AFFECTING DEATH RATES

1. life expectancy
   - -- ave # yrs a newborn can expect to live
   - -- range: 35 in Sierra Leone and Zambia to 82 in Japan.
   - -- U.S.: 1900 = 45, 2004 = 77
2. infant mortality rates
   - -- # die before age 1 per 1000 born
   - -- usually reflects: undernutrition, malnutrition, and high incidence of infectious disease (usually from contaminated drinking water).
   - -- range: 3 in Finland to 150 in Liberia
   - -- 6.7 in US, 25 in Mexico

POPULATION AGE STRUCTURE

A. Definition: the % of a pop of each sex at each age level

B. Important age categories are prereproductive (to 14), Reproductive (15-44), and postreproductive (45+).

C. Large Base represents built-in momentum for increasing pop size.

1. 2005: world – 29% prereproductive (<15 yrs old)
2. 21% < 15 yrs old in US and 31% in Mexico
2. This represents momentum that pop experts figure will keep our pop increasing until middle of next century, even if total fertility rate is brought below replacement-level fertility rate in the near future.

POPULATION DISTRIBUTION

A. Increasing Urbanization (% people living in cities)
   1. World: 1900 was 14%; 2005 was 47%
   2. U.S.: 1800 was 5%; 2005 was 79%
   3. Mexico 75%

B. Negative Effects of Urban Environment
   1. Cut down trees and name streets after them
   2. Urban Heat Island
   3. Dust Dome
   4. Production of vast amts of pollution in concentrated area (air, water, land, noise).
   5. Loss of land/water for agric. and wildlife.

C. Positive Effects of Urbanization
   1. Expanded life expectancy
   2. improved health and economic well-being
   3. improved education
   4. narrowed (but still pervasive)gender gap

POPULATION CONCEPTS

A. Lifeboat Ethics

B. Triage

C. Carrying Capacity vs. **Cultural Carrying Capacity**

-- Cultural Carrying Capacity: the maximum number of people an area can support forever at a given standard of living.

-- Robert Malthus said 200 yrs ago, "There should be no more people in a country than could enjoy daily a glass of wine and piece of beef for dinner."

APPROACHES TO POPULATION CONTROL

A. Controlling Migration

B. Voluntary Family Planning: economic development?

C. Involuntary Population Control
   1. limit # children
   2. licenses
   3. compulsory sterilization
   4. food rations so only 4-person family possible
   5. death control: infanticide, euthanasia

D. Economic Motivation
   1. incentives 2. deterrents

HISTORY

OVERVIEW OF RESOURCE USE, CONSERVATION, AND PROTECTION IN THE U.S.A.

Frontier Expansion (1607-1900)

Early Conservation Warnings (1832-1870): largely ignored

Beginnings of Federal Government's Role in Resource Conservation (1870-1916)

1st wave of resource conservation in National Parks, National Forests and Wildlife Refuges, Lacey Act (fed permit for transport of wildlife across states or into US).

Expanding Federal Role in Wildlife and Public Land Management (1933-1960)

2nd wave: CCC, Soil Erosion Service, Pittman-Robertson and Dingell-Johnson Acts, US Fish and Wildlife Service

Rise of the Environmental Movement (1960-1980)

3rd wave: Silent Spring, Wilderness Act, Clean Air Act, Emerging Science of Ecology, Earth Day

4th wave (1969+): Lots of Legislation including National Environmental Policy Act (EISs), End Species Act, Clean Water Act, Federal Land Policy and Mgmt Act (Multiple and Sustained Use), and started another sagebrush rebellion.

Continuing Controversy and Some Retrenchment (1980s and 1990s)

Reagan/Bush/Clinton era

2000s?

Bush

Your Chance to Affect What Happens!

SOIL

SOIL IMPORTANCE

- Soil is a happening place!!!
  - Soil consists of inorganic materials (clay, silt, sand) weathered from solid rock, living organisms (worms, insects, mites, fungi, microorganisms), decaying organic matter, water, and air.
- Soil is critical to all life (it's not just dirt!)-- soil is where the land, water, air, and life join
  - Soil processes are critical to driving biogeochemical cycles.
  - Except for carbon, everything else that makes up you ($C_{1480}H_{2960}N_{16}O_{1480}P_{1.8}S$) came from the soil.

SOIL PROFILE AND FORMATION

- Soil Profile:
  - **Topsoil** (A Horizon) is the upper layer that contains humus (decaying organic matter)
  - **Subsoil** (B Horizon) is where minerals leached from the topsoil accumulate
  - **Parent Material** (C Horizon) consists of newly weathered **bedrock**

- Soil formation involves parent material, climate, topography, organisms, and time
  - It takes **200-1000 years to naturally produce 1 inch of topsoil**; potentially renewable
  - Particle size affects nutrient- and water-holding capacity, permeability, aeration
  - Temperature affects rate of activity of organisms, warmer speeding decomposition
  - Cold water leaches iron and leaves silica, warm water leaches silica and leaves iron
  - Tropical Soils: shallow A horizon (rapid decomposition), constant warm rain leaches silica but leaves aluminum and iron compounds. When the forest is removed, the A horizon quickly washes away, exposing the aluminum and iron-laden subsoil to the heat of the sun which causes the iron-rich soil to harden, leaving the soil unproductive after a few short years.

SOIL EROSION AND CONSERVATION

Definition: movement of soil components, especially topsoil, from one place to another.

Rates of Loss

U.S.: One-third of cropland has a higher erosion rate than replacement rate.

Amount lost equals dump trucks 3500 miles long each year

World: amount lost would fill freight train encircling the Earth 150 times.

Remember: this is the loss of stuff that makes up key parts of you. Also, we're having to feed more and more people on less and less topsoil.

Two Main Erosional Forces: #1. flowing water #2. wind

Factors Making Land Susceptible to Erosion: #1.

Vegetation Removal (roots hold soil)

Activities that expose soil to water and wind include, overgrazing, logging, improper farming practices, construction, etc.

Effects of Soil Erosion:

1) reduced productivity (loss of nutrients, reduced nutrient- and water-holding capacity)
2) increased pollution (air and water pollution; sedimentation is the largest single source of water pollution)
3) increased flooding
4) gullying (loss of productive land altogether)
5) increased expenditures on fertilizers and irrigation
6) irrigation can lead to waterlogging and salinization.

Short-term cost of soil erosion in U.S. alone is estimated to be $24 billion annually.

Soil Conservation

1930s Dust Bowl finally made us realize the importance of soil and its conservation

1935: Soil Conservation Act established the Soil Conservation Service.

Conservation Methods: We know how to conserve soil, we just don't practice it

Keep the ground covered with vegetation

Use Conservation Tillage Farming Techniques (contour farming, terracing, strip cropping, crop rotation, windbreaks, etc.)

FOOD

OUR FOOD

Wheat, rice, corn, and potatoes make up more of world's total food production than all others combined. These are annuals, requiring yearly planting and soil disturbance.

The bulk of our food supply is based on only a small number of plant and animal species (90% of our food supply comes from only 20 crops [80,000 possible]; the bulk of our non-fish diet comes from just 8 species of domesticated livestock). This monoculture leaves our food supply more susceptible to disease, pests, loss of genetic vigor, etc.

Food accounts for 11-15% of disposable income spent in US, but most of rest of world spends 40-80%.

THE AGRICULTURAL SYSTEM

17% of workers in the private sector are in the US agricultural system (only 1% of US workers are farmers though).

Agriculture is the biggest industry in total annual sales and % private sector jobs.

Miller states, "Agriculture uses more of the earth's land, water, plant, animal, and energy resources [1/12 of world oil output; 17% of US commercial energy] and causes more pollution and environmental degradation that any other human activity."

OUTLOOK

So far, world per capita food production has kept up with the exponential increase in pop.

- However, 1 in 3 people in the world intake 90% or less of the amount of food a person needs to carry on daily life activities.

Will it continue to be able to keep up?

- Depends on what happens to population growth
- Depends on our ability to grow food

World fish catch is likely at the maximum sustained yield

THREE WAYS TO MAKE MORE FOOD AVAIL TO WORLD MARKET

1. BRING NEW LANDS INTO PRODUCTION

Only about 11% of Earth's land area is suitable for growing crops; currently we are growing crops on half of this. However, most of the best land is already in production and most of the potential new cropland is in remote rain forests where the soil cannot support intensive agriculture for long.

Current gains in area are being offset by losses in cropland due to conversion to other uses, soil erosion, and abandonment of mismanaged croplands.

Most assessments are that this will account for little increase in production in the future.

2. INCREASE YIELD

Green Revolution: dramatic increases in yield due to

applying inorganic fertilizer, pesticides, and irrigation water
- since 1950, see 4-fold increase in fossil fuel use, 17-fold increase in use of inorganic fertilizers, 32-fold increase in pesticides, 3-fold increase in amount of land irrigated.
- takes tremendous amount of energy. An average of 10 units of fossil-fuel energy is needed per unit of food energy on the table.
- see diminishing returns

Biotechnology Revolution: using scientifically-bred plant varieties (
- e.g. faster-growing (allows multiple cropping) wheat and rice varieties with larger seed heads

3. IMPROVE EXISTING FOOD SUPPLY

Switch to away from meat to vegetarian diet
40% of grain consumed in world is eaten by livestock (2nd law of thermodynamics); this number is 70% in U.S. Note: 5 kg of plant protein suitable for human consumption fed to livestock instead only results in 1 kg of livestock protein for human consumption.

Improve food storage

Improve food distribution: estimates of loss from storage and distribution are 5-30%

Improve nutrition
undernourishment: insufficient intake of calories (energy)
malnourishment: insufficient intake of protein

INTEGRATED PEST MANAGEMENT
Use a combination of the following to reduce pests below economic threshold:

a. modify cultivation procedure: polyculture, crop rotation, adjust planting timing
b. artificial selection and genetic engineering
c. biological control
d. insect traps and sterilizations
e. correct chemical use as last resort
f. **change attitude of consumer** to tolerate some blemishes.

UNCERTAINTIES ABOUT THE FUTURE

- What is the predicted climate change and how it will affect production?
- (especially changes in extreme values more than mean values)
- What is the physiological effect of rising atmospheric CO_2 in crops? (rising
- CO_2 may enhance photosynthetic uptake and plant growth if soil water and nutrients are not limiting)
- How are pest populations affected? (pest need to eat more because less nutrient content of plant tissue (e.g. high leaf C/N) the pest life cycle can be faster in a warmer climate)
- Pollutant concentration (tropospheric ozone has a negative effect on some crops)

BIOLOGICAL DIVERSITY

Paul and Anne Ehrlich (Healing the Planet, 1991): "The ravaging of biodiversity, in our view, is the most serious single environmental peril facing civilization. Biodiversity is a resource for which there is absolutely no substitute..." "Almost 40% of all potential NPP [net primary productivity] generated on land is now directly consumed, diverted, or forgone because of the activities of only one of millions of animals species -- *Homo sapiens*."

BIOLOGICAL DIVERSITY

- A. 1.5 million described species (estimate between 10 and 100 million species)
  1. __% animals, __% plants, __% fungi, __% protists, __% bacteria
  2. Animals Only: __% arthropods, __% insects, __% beetles, __% vertebrates
- B. Biodiversity Hotspots: areas with a high concentration of endemic species that already have lost 70% or more of their original habitats.

KINDS OF LOSSES

- A. Loss of Abundance
- B. Species Extinction
- C. Ecosystem Disruption

NATURAL EXTINCTION

- A. Mass Extinctions
  1. End of Cretaceous (65 mya): lost dinosaurs; 50% of genera; 15% of marine animal families.
  2. End of Permian (250 mya): 50% of plant and animal families; 67% of marine species.
- B. Average of 1 extinction/5-10 yrs between mass extinctions.

HUMAN-CAUSED EXTINCTION

- A. Current extinction rates (figs 14.9,14.10)
  1. 1600-1900: 1 species/yr
  2. Currently, an estimated 4000 - 36,000 species go extinct annually. E.O. Wilson (25-50% lost by 2050)
- B. Human activities involved in extinction.
  - #1: Habitat Alteration
  - #2: Introduced Species
  - #3: Overharvesting

SPECIES CHARACTERISTICS THAT AFFECT CHANCES OF EXTINCTION

Economic importance to humans; Specialized; Low Reproductive Rates, etc.

WILDLIFE PROTECTION

Species vs. Ecosystem Approach

THE ENDANGERED SPECIES ACT

1. **DEFINITIONS**
    - -- Species: "any subspecies of fish or wildlife or plants, and any distinct population segment of any species or vertebrate fish or wildlife which interbreeds when mature."
    - -- Endangered Species: "any species which is in danger of extinction throughout all or a significant portion of its range..."
    - -- Threatened Species: "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

2. **PROVISIONS**

    a. **Listing** (fig. 14.8 & table 15.1)
    - -- reflects our knowledge and special interest
    - -- species may be exempt if undue economic hardship
    - -- "God Squad" Committee composed of: Secretaries of Interior and Agriculture, Head of EPA, Head of Army, Chair of Council of Economic Advisors, State Representative

    b. **Protection Measures**
    - -- **protects individuals** by prohibiting hunting, killing, capturing, selling, importing, or exporting any endangered species or products.
    - -- **protects critical habitat:** "specific geographic areas that are essential for the conservation of a threatened or endangered species".
    - -- forbids gov't or gov't-sponsored activities that might threaten

    c. **Recovery Programs**: recovery team and recovery plans

3. **APPLICATION**

a. The snail darter vs Tellico Dam: exempted

b. The American Alligator: successful; endan. in 1967, removed 1987

c. Kirtland Warbler: couldn't be successful because international problem. The bird needs young, widely-spaced jackpines (appear following forest fires); prescribed fires but still see decline. Found winter habitat in Bahamas lost to development.

Convention on International Trade in Endangered Species (CITES 1975)

ZOOS AND GENETIC BANKS

a. Captive Breeding and Reintroduction Programs
b. Problems: with breeding, survival, reintroduction

- -- Inbreeding Depression: (also minimum viable pop size)
- -- an accumulation of harmful genetic traits through random mutations and natural selection that lowers reproductive success

Preserves, parks, refuges (410; 1% of US), wilderness areas, etc.

- -- **Theory of Island Biogeography**
  - -- smaller islands have fewer species than larger islands, and farther islands have fewer species than islands closer to the mainland or other sources of recruitment.

The Rivet Popper Analogy

Suggested Reading: *Easter's End* by Jared Diamond in Discover, Aug. 1995

ENVIRONMENTAL ECONOMICS

ECONOMICS

The study of the production, distribution, and consumption of goods and services.

GNP: the dollar value of the goods and services generated in a country. Often used as an index of quality of life erroneously.

Economic Needs and Wants

Needs: must have to stay alive and healthy
Wants: everything else

Ecological Footprint

Land area required to sustainably support one person, city, etc. For example, see:
http://www.earthday.net/footprint/index.asp

Law of Diminishing Returns

Each additional unit of effort (resources) yields less results.
Example: Optimal Pollution Control

Opportunity Cost

Definition: What else you could have been doing with your resources (e.g., money).

"Every action you take, every dollar you spend, every hour you use, and every course you take, has an opportunity cost in terms of the alternative uses for the time and/or money spent."

Internalizing External Costs (Ecological Impact Costing)

"Perhaps the chief fact relating economics and the environment is that in the past, ecological and environmental factors were not taken into account as part of the cost of doing business." We now use ecosystem valuation to attempt to place dollar values on ecosystem services such as clean air, clean water, soil formation, etc.

Internal Costs: costs paid directly by the consumer (called private costs in book)

External Costs: costs not included in market price but ultimately paid by someone -- you, others, society, or future generations. Example: gasoline at the pump.

True Cost: internal costs plus external costs (both short-term and long-term)

Advantages of Internalizing External Costs (called ecological impact costing):

- redirect economic growth in ways that consider long-term societal impacts
- paying real price lets market regulate

Disadvantages of Internalizing External Costs:

- difficult to determine external costs
- higher prices will allow competitors that don't charge true cost to outcompete.

AIR POLLUTION EXAMPLE

AIR POLLUTION

INTRODUCTION

You exchange 35 lbs of gases/day (6x more than food and water)

But air is not composed only of gases -- also liquids and solids

Gases: 78% N_2 21% O_2 0.9% Argon 0.035% CO_2

Liquids: water, acids, etc.

Solids: dust, pollen, soot, etc.

Pollutants -- affect health, survival, or activities of humans or other living organisms.

<u>Sources</u>

Natural versus **Human**

Stationary (easier to monitor) versus **Mobile**
- autos are 2/3 of weight of human-produced air pollution in U.S.

Primary (enters the air directly) versus **Secondary** (formed in the air through chemical reactions between primary pollutant and one or more air components, often in sunlight (photochemical smog))

<u>Effects</u>

- Nuisance and aesthetic
- Property damage; e.g. ozone weakening rubber
- Damage to nonhuman organisms
- Damage to human health
  - **acute**: short duration exposure and/or immediate effects
  - **chronic**: long duration exposure and/or long term effects
    - more difficult to pinpoint the cause
- Disruption of natural life-support systems at local, regional, and global levels

Factors Affecting Effects

Chemical nature: how active and harmful it is

Concentration: amount per volume (affected by weather, topography, etc.)

Persistence: how long does it stay around

LAWS AND CONTROL

Clean Air Act (1970 then amended in 1974,1977, 1990)

Established National Ambient Air Quality Standards (NAAQS) and Emission and Performance Standards.

EPA established in 1970 to be in charge of environmental programs including the Clean Air Act. Much of responsibility of carrying out Act delegated to States.

1. **Criteria Pollutants**: NAAQS – national ambient air quality standards (how much can be in the air)
   - -- Six Pollutants: use **SPLONC** to remember sulfur dioxide (SO_2), particulate matter, lead, ozone (O_3), nitrogen dioxide (NO_2), and carbon monoxide (CO).
   - -- Primary standard protects public health
   - -- Secondary standard protects public welfare (all nonhealth effects)
   - -- Air Pollution Index: based on 100 as at the NAAQS

2. **Noncriteria Pollutants**: emission standards (how much can come out of the "smoke stack")
   - -- Limit on amount of a pollutant that may be discharged from specific source
   - -- Performance standards: emission standards for different classes of polluter
   - -- Set for only a few of the 600^{+}potentially toxic compounds: arsenic, asbestos, benzene, beryllium, mercury, vinyl chloride, and radioactive isotopes

MAJOR EFFECTS AND SOURCES OF CRITERIA POLLUTANTS

1. **Sulfur Dioxide (SO_2)**
   Effects: corrosive gas directly damaging to plants and animals; forms sulfuric acid which damages lungs (2nd to smoking); acid deposition
   Sources: mostly stationary fuel combustion (80%), especially coal burning

2. **Particulate Matter < 10 μm**: -- e.g., dust, soot, lead, arsenic, asbestos, etc.
   Effects: depend on pollutant; usually decreased lung function
   Sources: mostly industry (38%) and stationary (25%) and mobile (21%) fuel combustion
   In Arizona and other arid areas, this is an especially big problem due to small soil particle size and arid conditions.

3. **Lead**
   Effects: hinders normal development of brain -- mental retardation, behavioral problems, etc. Hinders production of hemoglobin. May harm kidneys.
   Sources: mostly combustion of leaded gas in past; also paints and smelting plants.

4. **Ozone (O3)**
   Effects: strong oxidizing reagent and damages vegetation, buildings, sensitive tissues like eyes and lungs (emphysema, etc.).
   Sources: mostly transportation and stationary fuel combustion; product of nitrogen dioxide, hydrocarbons, and sunlight

5. **Nitrogen Dioxide (NO_2)**:
   Effects: gives photochemical smog its distinctive reddish-brown color; acid deposition; diminished pulmonary function; formation of ozone
   Sources: mostly fuel combusion (both transportation and stationary)

6. **Carbon Monoxide (CO)**:
   Effects: reduces blood's capacity to carry oxygen, reacts photochemically to produce O_3
   Sources: mostly transportation

TEMPERATURE INVERSIONS: WORSEN PROBLEM

-- normally air temp decreases with increasing altitude; adiabatic cooling

-- ground heats up and heats air above it which rises, expands, and cools

-- pollution rises with the warm ground air and ground-level pollution is decreased and the air becomes mixed.

-- if cool air is created under or slips under relatively warmer air so that the temperature of the air at ground level is cooler than the air just above it, then a temperature inversion occurs.

-- because the cool air just sits on the ground and does not mix, air pollutants build up in this layer.

-- the inversion will be broken up when the ground heats enough to heat air to break up inversion.

-- especially prevalent in cities surrounded by mountains or between mountains and an ocean.

-- tall smokestacks pierce the inversion layer to send the pollutants elsewhere.

SOLUTIONS:

Pollution Prevention (Input control): prevent pollutants from being formed in first place by reducing, recycling, and reusing (see p. 19). Benjamin Franklin's quote, "An ounce of prevention is worth a pound of cure."

Examples: Reduce pop. growth, reduce use, increase energy efficiency, switch to cleaner fuels, switch from fossil fuel use to solar/wind/water energy.

Pollution Cleanup (output control): cleanup after production by smokestacks, scrubbers, catalytic converters, incineration, taxing emissions. Buys us time but eventually overwhelmed by exponential increase in production.

Has problems:

- Temporary bandage: buys us time but eventually overwhelmed by exponential increase in production. Ex. catalytic converters reduce pollutants emitted but more cars may override this benefit
- May just move the pollution around: garbage burned just moves to air
- Relies on laws and enforcement is problem

TRENDS IN MAJOR AMBIENT AIR POLLUTANTS

Estimated savings of $21 billion from 1970 to 1978 as a result of the approximate 20% reduction in air pollution due to the Clean Air Acts.

Air pollution cleanup cost $85 billion in 1987; est. of $148 billion in 2000

MAJOR TYPES OF INDOOR AIR POLLUTION

-- For most people indoor air pollution poses a much greater threat to their health than outdoor air pollution; yet EPA spends 100x more on outdoor.

-- Ironically, energy conservation through better insulation increases health risk by indoor air pollution (e.g., radon)

1. Cigarette Smoke: "Smoking tobacco causes more death and suffering by far among adults than any other environmental factor." Miller 1992.

2. Many others

GLOBAL AIR AND CLIMATE IMPACTS

OZONE DEPLETION

THE ATMOSPHERE: a layered envelope

1. Troposphere (0-10 mi; thick as an apple's skin): much mixing; weather
2. Stratosphere (10-30 mi): contains the ozone layer; slow horizontal air circulation

WHY IS OZONE IMPORTANT?

1. Destructive Tropospheric Ozone -- part of urban smog
   -- Ozone damages respiratory systems, irritates eyes, damages plants, damages building materials such as rubber, paint, and plastics.

2. Beneficial Stratospheric Ozone -- the ozone layer
   a. Beneficial UV blocker -- our global sunscreen
      -- UV radiation is powerful enough not only to give sunburns but also to break apart DNA and other biological molecules. This leads to increases in skin and eye cancer, cataracts, and damage to other organisms.

Stratospheric Ozone Formation and Destruction

1. O_2 + UV = O + O; O + O_2 = O_3; O_3 + O = $2O_2$

2. $CFCl_3$ + UV = $CFCl_2$ + Cl; Cl + O_3 = ClO + O_2;

   ClO + O = Cl + O_2 (one Cl may break up 100,000 mol of O_3)

3. CFCs emitted by leaking air conditioners and refrigerators; evaporation of industrial solvents; production of plastic foams; and aerosol propellants releases Chlorine (Cl) which destroys Ozone.
4. Bromine (Br): more effective than Cl as ozone destroyer. Found in methyl bromide, an agricultural fumigant for which there is no good substitute at the present. Note: other ozone destroyers include methyl chloroform, carbon tetrachloride, bromine-containing halons (fire extinguishers)

4. Effects of Ozone Loss -- Speculative
   a. Each 1% loss in ozone leads to 2% inc in UV, which leads to 5-7% inc in skin cancer, including a 1% increase in deadly malignant melanoma. EPA estimates that each 1% decrease in stratospheric ozone could result in 43,000 new cases of skin cancer annually and 24,000-57,000 more cases of cataracts annually.
   b. Other effects include immunosuppression, intensification of certain skin diseases (eg. leprosy, smallpox, etc.), an increase in photochemical smog such as ozone (each 1% decrease in strat. ozone may cause 2% incr in tropo. ozone), decreased food crop yield, decreased growth of phytoplankton, property loss of $2 billion.

5. <u>Ozone Depletion (Hole) History</u>
   1. 1930: CFCs developed (stable and non-toxic)-- used as coolants, propellants, clean electronic parts (eg. computer chips), hospital sterilants, granary fumigant, create bubbles in styrofoam. US top producer.
   2. 1973 chemists hypothesized that CFCs were lowering stratospheric ozone.
   3. 1978 ban on CFCs in most aerosol cans (but only accounted for 25% of use)
   4. 1985 study results show big ozone hole over Antarctic.
   5. 1987 **Montreal Protocol** -- international treaty to cut use of CFCs in half by the year 2000.
   6. 1990 -- time-table moved up to cut production of CFCs 20% by 1993, 50% by 1995, and 100% by 2000.
   7. 1992 -- Bush calls for eliminating production of CFCs by end of 1995.
   8. 1995 – CFCs are banned in the U.S., but ozone layer still being affected by CFCs emitted years ago.

ACID DEPOSITION

A. pH Scale
1. Ranges from 1-14; low = acidic; logarithmic scale (10-fold change between numbers)
2. Natural precipitation is 5.6; average precipitation in eastern US is 4.3 (tomato juice)
3. **Buffer Capacity**: ability of a substance to neutralize an acid or base; varies with substrate.

B. Sources: But may travel far distances
1. carbonic acid created by CO_2 in the air
2. volcanic emissions, ocean spray (chlorine and sulfates), biological decomposition
3. fossil fuel burning (sulfur dioxide and nitrogen oxides)

C. Causes
-- Sulfur dioxide and nitric oxide emissions form secondarily nitric acid, sulfuric acid, and sulfate and nitrate salts. These descend to Earth's surface as acid deposition (wet and dry).

D. Effects
1. Kills aquatic organisms (1000s of lakes "dead")
   a. reproduction affected: eggs and fry most sensitive
   b. aquatic plants and inverts are affected and they form base of food chain
   c. how fish are killed: alters body chemistry, destroys gills, causes bone decalcification, disrupts muscle contraction.
   d. toxic metals such as aluminum are leached out of rock and soil

2. Kills forests (Camel's Hump Mt. in Vermont: 1980 survey showed 50% decline in spruce-fir forests in upper elevations in 15 yrs; 1990 almost all the red spruce, once dominant, were dead or dying)

   Increased susceptibility to death from frost, pests, and disease due to:

   a. Direct damage to leaves and bark

   b. Soil acidification, which leads to reduced nutrient and water uptake due to

   - leaching of soil nutrients
   - kills certain essential soil microorganisms
   - release of toxic metals which damage fine roots

3. Damages buildings: $ billions/yr in US

GLOBAL CLIMATE CHANGE

GREENHOUSE EFFECT

Definition: trapping and buildup of heat near the earth's surface (troposphere). Water vapor and various gases (greenhouse gases) absorb and reradiate heat back to the earth's surface that would have gone out to space.

Greenhouse Gases: water vapor and CO_2 (49%), Methane (18%), CFCs (14%), nitrous oxides (6%), other gases (13%)

GLOBAL WARMING

Definition: upward trend in global temperatures largely due to human activities.

Things We Know

- Earth's climate results from complex interaction that we only partly understand.
- Earth's average temperature has fluctuated considerably over geologic time.
- Estimated changes in tropospheric CO_2 correlate with estimated average temps.
- Measured atmospheric levels of certain greenhouse gases have risen in recent decades.
- Since 1860 when records began, average global temp has risen 0.5-1.1 degrees F
- Temp changes since 1860 have been too small to exceed normal short-term swings in global temps.

Things We've Learned from our Computer Models of Climate

- Average Global Temp will rise 2.7-9.9 degrees F as CO_2 concentrations double by the year 2050-2075 if inputs of greenhouse gases continue to rise at current rate.
- Average Sea Level will rise 0.8-1.6 inches per decade under above scenario.
- Temp and Precipitation patterns will change across the globe.

Things We Don't Know

- Degree to which humans are to blame for recent rise in global temps
- How Earth's Climate System Works: e.g. role of oceans, polar ice, clouds, air pollution, volcanos, reaction by land and sea plants, soil, etc.
- Effects of global warming at any given area

Suspected Causes of Increasing Concentrations of Greenhouse Gases

Sources of Greenhouse Gases

- CO_2: fossil fuel burning (65%), land clearing and burning (33%), cement (2%)
- Methane: livestock (30%), rice paddies (29%), pipeline leaks (21%), solid waste (14%), and coal-burning (6%)
- Nitrous Oxide: from nylon production; burning of biomass and nitrogen-rich fuels (esp coal); and breakdown of nitrogen fertilizers in soil, livestock wastes, and nitrate-contaminated groundwater.

Reduction of one of two CO_2 sinks (forests, but not ocean phytoplankton yet)

Effects of Global Warming

Agriculture: shifts in precipitation pattern
Biotic Communities would have to shift
Coastal Areas would become flooded with thermal expansion of oceans and melting of ice caps.
Weather hazards may increase in intensity or abundance: e.g. hurricanes
Human Health

DEBATE

Not much on whether global warming is happening.
Much on what all is causing it and what its effects will be.

SOLUTIONS

Input pollution control: switch energy sources, halt CFCs, etc.
Output pollution control: harvest methane, etc.
1990: World Climate Conference in Geneva Switzerland: Soviet Union and US refused to commit to specific reductions because of scientific uncertainties and economic constraints.
1992: U.N. conference: U.S. refused again. Want commitment by June for UN Conference on the Environment and Development.
1997: Kyoto Protocol
1998: Kyoto Protocol revisited
2000: Kyoto Protocol revisited
2001: Kyoto Protocol refused by U.S.A., but accepted by other countries
2002: Kyoto Protocol refused by U.S.A., but accepted by an increasing number of countries, including Japan.
2005: Kyoto Protocol ratified (but not by US)
2006: 163 countries have ratified the agreement (61.6% of Annex I emissions countries) Still refused by USA and Australia.

ENERGY

Kupchella and Hyland (1993) very eloquently state the importance of energy to humans. The authors make two important statements:

1) "In short, we humans use energy to make the world as we like it and then use still more energy to keep it that way"
2) "Nearly every environmental problem is directly related to the production and consumption of energy"

ENERGY SOURCES

<u>History of Energy Use</u>

- Historical: Wood (to 1880), Coal (1880-1950), Oil Eras (1950-present)
  - Increasing reliance on nonrenewable sources (from 9% in 1850 to 96% in 1989)

<u>Current energy sources</u> for world and U.S.

- (nonrenewable vs potentially renewable)
- World: 17% Perpetual or potentially renewable (11% biomass, 6% other)
  - 83% Nonrenewable (78% fossil fuels, 5% nuclear)

- MDCs: 90% Nonrenewable; 10% Renewable

- LDCs: 59% Nonrenewable; 41% Renewable

- U.S.A. 09% Perpetual or potential renewable (4% biomass, 5% other)
  - 91% Nonrenewable (84% fossil fuels, 7% nuclear)

ENERGY USE

Increasing exponentially since 1850.

Per capita energy use comparisons among nations
Note: USA with 4.7% of world's people uses 25% of commercial energy
Note: in 1993 the 258 million in US used more electricity for air conditioning alone than the 1.2 billion Chinese used for all purposes

Industry: 37%; Transportation: 25%; Residential: 22%; Commercial: 16%

U.S. Energy Flow

Flow Through US Economy Chart: 9% useful energy, 7% petrochemicals, 41% unavoidable waste (2nd law), 43% unnecessary waste (fuel-wasting vehicles, etc and leaky bldgs.)

"People in the United States unnecessarily waste as much energy as two-thirds of the world's population consumes." Miller 1996

ENERGY SUPPLIES
Resource Reserves vs Resources

THREE BASIC APPROACHES TO MEETING ENERGY DEMANDS

1. **Develop new sources**

Pros: don't need to change current patterns of energy use; may switch to cleaner sources of energy.
Cons: may not switch to cleaner sources of energy but do even more environmental damage; may not keep up with increasing demand.
"About 92% of the known reserves and potentially available energy resources in the United States are renewable energy from the sun, wind, flowing water, biomass, and Earth's internal heat." Developing these mostly untapped renewable energy resources ... could meet 50-80% of projected U.S. energy needs by 2040 or sooner..." Miller 1996:97

2. **Improve energy efficiency**

Pros: extend existing energy supplies
Cons: involves converting to new systems

Energy Efficiency: % of total energy input that does useful work and is not converted to heat in an energy conversion system.

- -- Examples include: insulating buildings; tuning car engines; using more energy efficient cars, heating and cooling systems, appliances, lights, industrial processes, etc.
- -- Example: incandescent light bulb should be called a heat bulb because it is only 5% efficient; 95% of energy is converted to heat.

Net Energy Efficiency

Net Energy Efficiency: % of total energy in source that does useful work; takes into account net efficiency of the entire energy delivery process including all energy that is lost and wasted in finding, extracting, processing, transporting, and using the energy source.

Life-cycle Cost = initial cost + lifetime operating costs

3. **Adopt new lifestyle**

Pros: an input approach
Cons: harder to get support
Examples include: using mass transit, wearing sweater instead of turning up thermostat, turning off unneeded lights, eat locally-grown food, consume less meat, etc.

PRINCIPLE OF MATCHING ENERGY QUALITY TO ENERGY TASKS

"The more it costs, the smarter we seem to get."
Start with energy end uses and then match best sources.

DEVELOPING AN ENERGY STRATEGY

EVALUATING ENERGY RESOURCES

1. What do we need energy for and how much do we need for each task.

2. What type and quality of energy best performs these tasks.

3. Among energy alternatives, ask four questions:

    i. How much will be available during the short, intermediate, and long term?

    ii. What is the net energy yield?

    iii. How much will it cost to develop, phase in, and use?

    iv. How will extracting, transporting, and using it affect the environment?
    Include hidden (real) costs of energy use

ENERGY ALTERNATIVES

Nonrenewable: finite supply
Fossil Fuels, Nuclear

Potentially Renewable: has a maximum sustained yield.
<u>Maximum Sustainable Yield</u>: highest rate at which a potentially renewable resource and be used without reducing its available supply.
Biomass, Hydrogen

Perpetual: will not run out as long as the sun shines
Improve Energy Efficiency, Solar, Hydropower, Wind, Geothermal, etc.

LAND RESOURCES

LAND AS A RESOURCE

U.S. Land Ownership: 59% private; 31% federal govt; 7% state or local govt; 3% Indian tribes

Types of Land Use: Commercial/industrial, residential, energy/mineral reserves, cropland, pasture and grazing, tree farms, natural, etc.

Deciding among competing land uses: On What Bases Should Decision be Made?

- Selling Price? Meeting Food Needs? Meeting Resource Needs? Other?
- Who Should Decide? Landowner? Government?

FEDERAL LANDS AND LAND USE MANAGEMENT

STATISTICS

31% of all U.S. land is managed by federal govt; 73% of this land is in Alaska, 22% is in the western states, and only 5% is in the eastern states.

Breakdown of public land management

- 50% is managed by the Bureau of Land Mgmt. (BLM) (Dept. of Interior)
- 25% is managed by the U.S. Forest Service (Dept. of Agriculture)
- 10% is managed by the National Park Service (Dept. of Interior)
- 10% is managed by the U.S. Fish & Wildlife Service (Dept. of Interior)
- 4% is managed by the Dept. of Defense; other 1% by Bureau of Reclamation, etc.

<u>**MAJOR COMPONENTS OF FEDERAL PUBLIC LANDS**</u>

1. ***National Forests***: U.S Forest Service
   -- Multiple Use and Sustained Yield (consider all uses – timber, grazing, mining, oil and gas extraction, recreation, wildlife – and use resources only as fast as they replenish themselves)

2. ***National Resource Lands (BLM Lands)***: Bureau of Land Management
   -- Multiple Use and Sustained Yield

3. ***National Wildlife Refuges***: U.S. Fish & Wildlife Service
   - -- Each refuge has specific objectives, usually providing habitat for one or more specified species
   - -- Sport hunting, trapping, sport and commercial fishing, oil and gas development, mining (old claims), timber cutting, grazing, and farming are allowed as long as Secretary of Interior deeds compatible with purposes of each unit.
   - -- There are 521 refuges currently

4. ***National Parks***: National Park Service
   - -- Preserve “unimpaired” but promote the use of the National Parks

5. ***National Wilderness Preservation System***: USFS, USF&WS, BLM, and NPS
   - -- Managed "for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness."
   - -- Hiking, camping, sport fishing, and in some areas sport hunting and horseback riding are allowed, but no motorized vehicles or man-made structures or roads, timber harvesting, grazing, mining except when occurred before designation are allowed.
   - -- Occur within Nat. Parks, Nat. Wildlife Refuges, Nat. Forests, and Nat. Resource Areas.