Imagine this: You're an ecologist working in a tropical forest in Brazil. You've just finished dinner, and you carry a chair to a nearby clearing to escape the noise and stink of the field station. And this is what happens, and what you think.

In the Amazon Basin the greatest violence sometimes begins as a flicker of light beyond the horizon. There, in the perfect bowl of the black night sky, untouched by light from any human source, a colossal thunderstorm sends its premonitory signal and begins a slow journey to you...and you think, my God, the world is about to change. You sit in the dark, at the edge of the rain forest 80 miles North of Manaus, working your mind through the labyrinths of field ecology and ambition....you're tired, and ready for change.

You sweep the ground with the beam from your headlamp for signs of life and find--diamonds! At regular intervals, intense pinpoints of white light wink on and off with each turning of your lamp. They are reflections from the eyes of wolf spiders, on the prowl for insect prey. When spotlighted, the spiders freeze, allowing you to approach on hands and knees and study them at almost their own level. You can distinguish a wide variety of species by size, color, and hairiness. It strikes you how little is known about these creatures of the rain forest, and how deeply satisfying it would be to spend months, years, the rest of your life in this place until you knew all the species by name and every detail of their lives. A riot of diverse forms of wolf spiders occupy the whole world, of which this is only the minutest sample, yet even these species turning now to watch you from the bare tropical soil could give meaning to the lifetimes of many naturalists.

The storm grows closer until sheets of lightning spread across the western sky. The thunderhead rears up like a top-heavy monster in slow motion, tilts forward, and blots out the stars. The forest erupts in a simulation of violent life. Lightning bolts break to the front and then closer, to the right and left, 10,000 volts dropping at 600 miles an hour, kicking a countersurge skyward ten times faster, back and forth in a split second, the whole thing perceived as a single flash and crack of sound. The wind freshens, and rain comes stalking through the forest.

In the midst of this chaos something catches your attention. The lightning bolts act like strobes to illuminate the wall of the rain forest. At intervals you
glimpse the storied forest: top canopy 100 feet off the ground, middle trees spreading raggedly below that, and a lowermost scattering of shrubs and small trees. The forest is framed in a few moments in this theatrical setting. Its image turns surreal, projected into the unbounded wildness of the human imagination, thrown back in time 10,000 years. Somewhere close, you know spear-nosed bats fly through the tree crowns in search of fruit, palm vipers coil in ambush on the roots of orchids, jaguars walk the river's edge; around them all, 800 species of trees stand tall, more than are native to all of North America; and a thousand species of butterflies, 6% of the entire world fauna, wait for the dawn.

...this was written by E.O. Wilson, a biologist from Harvard, and one of America's greatest living scientists, in his introductory book on the diversity of life, which he calls biodiversity. Wilson is about as "sciency" as you can get...brilliant, socially awkward, confident. But what rings truest from this account of a night in the amazon, is his sense of wonder, and his poetry. Yes, you can be a scientist and poet. Indeed, the best scientists...and the best poets...are both.

This lecture and next, we'll go over the concept of biodiversity.

I. Ecosystems and Natural Communities
A. Levels in an ecosystem and their definitions.
   1. Ecosystem. The system in which non-living elements are brought in to the tissues of living organisms is called an ecosystem. In the Amazon Basin, this is the soil, the rain, the lightning, the sun, the soil, the trees, the wolf spiders, the jaguars....and you. It's everything.
   2. Biotic community. The living part of an ecosystem is divided into distinctive groups of plants and animals, called communities. For example, the forest includes trees that stretch to the canopy; they are part of one community. It also includes understory herbs; they are part of a second community. The unique plants growing just along the river's edge; they are part of a third community, etc. In each of these, the animals present complete the community. The spear-nosed bats contribute to the canopy community, the wold spiders are part of the herb layer community, and the jaguar is a rare but brilliant part of the river's edge community.

B. Matter and energy
   1. Basic assimilation of the earth, sun, and water into life.
      a. All plants and animals are made up of stuff, matter, that occurs on the earth and in its atmosphere. Carbon, Hydrogen, Oxygen are the bigeese, and they come from the atmosphere in the form of CO₂ and in water H₂O. Everything else [nitrogen, phosphorous, calcium, potassium, sulfur, iron, sodium, and all the trace elements (e.g., zinc)] are in the crust of the Earth, dissolved in water, or both.
      b. Because of photosynthesis, green plants have the exclusive ability to take CO₂ from the air and H₂O from water and energy from sunlight to create sugars, releasing O₂ in the process. Other kinds of bacteria and algae convert atmospheric nitrogen into nitrates and nitrites in the soil, which plants then absorb through their roots. To these,
they add other stuff to form fats, proteins, and complex carbohydrates to generate plant tissue. In short, plants take H2O and CO2, which we have too much of, and produce wood, which we don't have enough of; giving off oxygen, which we can't live without, in the process. We learn this is third grade, but for some reason, the simple, elegant, and essential utility of a plant is often, and tragically, overlooked.

c. Animals then eat the plants, and breathe the oxygen to form their tissues. Other animals eat those....and so on. Thus, we see the basic trophic (to eat) structure...

2. Trophic levels

   a. Primary producers. These are the photosynthetic plants (on land) and blue-green algae (in the ocean) that obtain energy directly from the sun to build organic molecules.

   b. Second level consists of herbivores (aka primary consumers) which each photosynthetic species.

   c. Third level consists of predators (aka secondary consumers) that feed on the herbivores.

   d. Fourth levels consists of secondary predators (aka top carnivores) that eat other predators....and so on.

   e. Makes a nice tidy food chain, which is course too simple...in reality we have a food web, OVERHEAD, because for example grasses may be eaten by many herbivores, some of which may or may not be also consumed by predators and top carnivores.

   f. Such animals that are not eaten by a higher level, are assimilated by decomposers.

   g. Much of wildlife conservation is concerned with the actions of particular elements in these webs...how we can avoid losing elements?, how to bring earlier losses back?, how to make one elements especially abundant without disrupting everything else too much?, etc.

3. The transfer of energy from one tropic level to another is inefficient (second law of thermodynamics).

   a. Much energy is lost as heat during each transfer. Plants lose heat in photosynthesis. Animals lose plant heat, carnivores lose animal heat. The rule of thumb is that approximately 10% of the energy at one level is converted into energy at the next higher level. This has two profound consequences.

   b. Less energy is available at each successive tropic level in an ecosystem. These equates to dramatic declines in the number of organisms (biomass to be more specific) as you go up trophic levels in an ecosystem. In that tropical forest, there are millions of plants in 1,000 acres, thousands of fruit eating bats, a few bat-eating snakes, and perhaps only 1 jaguar. Thus, we see the trophic pyramid.

   c. The length of a food web is limited. Very little energy remains after three or four steps. Therefore, regardless of the total productivity of an ecosystem, they almost always have only 3 or four levels.

II. Biodiversity

   A. What is it? OK, so we see all these cogs in the web of life. How many are there, how different are they, we do they occur?, etc. This is the study of the diversity of life, the focus of E.O. Wilson's book, the realm of biodiversity.

   1. Hierarchy. Biodiversity is the wealth of life on earth, the organisms, the genes they contain, and the intricate ecosystems they contribute to the environment. Thus, we must consider the diversity of life at three fundamental levels. OVERHEAD

   2. Species diversity.
a. This is the most obvious. A tropical rainforest has very high species diversity because they are so many different kinds of organisms living there. What is a species? Biologists still can't quite nail it down, which serves as an example of complexity of life, but functionally, we can think of species as groups of organisms that share genetic heritage, and are morphologically, physiologically, or biochemically distinct from other groups. The species diversity of the earth thus contains the full spectrum of organisms on earth, from bacteria to caribou, to redwoods.

b. Problems in distinguishing and identifying species are more common than many people realize. For example, some organisms look superficially very different from one another, but share genetic material to a significant degree, and can freely interbreed. They are the same species....domestic dogs are an example. Chihuahuas and Great Danes are the same species, Canis domesticus. But other forms may look superficially very similar, but differ in meaningful genetic, and behavioral ways. Flycatchers are a good example. You can hardly tell them apart, except that willow flycatchers always live woods near water and say fitz-spew, while Dusky flycatchers live in dry forests and say pree tick preet

3. Genetic diversity. On a finer scale, biological diversity includes genetic variation within a species, both geographically separated populations (red and yellow-shafted Northern Flickers) and variation within single populations (morphs...blue and white Snow Geese).

4. Community or ecosystem diversity. The magnitude of biodiversity within an ecosystem is amazing. Take the rain forest example. The amount of different genetic material in all the life forms in that Brazilian forest could fill 15 volumes of the Encyclopedia Britannica. But what is even more amazing is that in the Philippines, where the climate has some obvious similarities to that in Brazil, you would an encounter an equally diverse rain forest that shares almost no species with that of the Brazilian forest. That is ecosystem diversity.

B. Measuring biodiversity. Actually measuring and putting numbers to this dizzying diversity is difficult to do, but we've got some ways to "index" diversity, which is to say to put a relative number on diversity. So, for example, we could measure the diversity of that Brazilian forest and say it is 20. 20 what? 20 nothing, just 20. Then we could measure the diversity of the Philippine forest and say it is 22...close the Brazilian forest's diversity, and then measure a forest in Massachusetts and say it is 3, much less than in the tropics. Thus, we have an index, or a relative measure, of diversity.

- Alpha, beta, gamma. Ecologists recognize three levels when measuring diversity.
  1. Alpha diversity is "within" habitat/ecosystem diversity. The simple number of species in a habitat, often called "species richness" is one measure of alpha diversity, but it is weak because a forest that has 99 caribou and 1 moose would have the same species richness (2 species) as a forest with 50 caribou and 50 moose, even though the latter is more diverse. More sophisticated measures of diversity account for this "species evenness," but remain measures of the diversity within a particular habitat or ecosystem.
  2. Beta diversity is "between" habitat/ecosystem diversity. This is the degree to which species change along an environmental gradient. A mountain has more diversity than a prairie because the mountain contains many habitats in its area (foothills, steep slopes, rivers, alpine areas), whereas a prairie is more uniform.
  3. Gamma diversity is "regional" diversity. This is the degree to which species change among regions that house similar habitats. For example, two adjacent mountains may each contain high beta diversity from foothill to alpine, but if they each share the same
suite of species, gamma diversity is low. If they each have different species, gamma diversity is high. Another example: equatorial forests, which include the Brazilian and the Philippine rain forests have very high gamma diversity because not only is each diverse in its own right, but they have very little overlap. In contrast, boreal forests, which include the pine/spruce forests of Siberia as well as Canada, have low gamma diversity because Siberia and Canada share many species in common.

C. Where is it found? The highest biodiversity is found tropical forests, coral reefs, large tropical lakes, and the deep sea.

1. In tropical forests, the big contribution of biodiversity is from a single class of animals -- the insects. Flowering plants are very diverse in the tropics, and many, many insects have specialized to feed on various parts of each of these plant species. The number is staggering. Wowee anecdotes....

2. The diversity in coral reefs is much more spread out....coral, algae, sea anemones, fish, etc....

3. The diversity in the deep sea may stem from the fact that it is so old and stable....it has given evolution enough time to work its way into a bewildering array of co-existing life forms.

4. The diversity of tropical lakes is like that on tropical islands. Each is very productive, allowing the specialization of many forms of animals, but each is isolated from the next, so each has evolved its own unique suite of species, many of which perform similar functions, but are nonetheless, different species. This is sometimes called parallel evolution. A good example of this is seen in birds on Caribbean islands. Each island has a small, a medium, and a large billed hummingbird to feed on flowers with small medium and large corollas, respectively. But most islands have a unique suite of 3 species.

5. In general, biodiversity increases as you approach the equator. Why? Warmer, older, more climatically stable? Probably all of the above....Examples of countries of similar size.

D. How many species?

1. At present, about 1.5 million species have been described. Most of these are insects and plants. Overhead.

2. At least twice this number, and likely 4 times this number, of species remain undescribed. Most of these undescribed species are insects in tropical forests....if you want to be a tropical forest insect identification expert....you will always be able to find a job.

3. Also, some recent work suggests that the number of bacteria species living in the soil may be nothing short of phenomenal. Thousands in every gram. Overhead.

**LECTURE 2b - BIODIVERSITY II**

Biodiversity -- so what? Remember the first day, and the inclusive definition of wildlife.....wildlife diversity it is synonymous with biodiversity...from echinoderms to elephants.

Why should society care about biodiversity?

I. Negative values of biodiversity. I mean, come on…all biodiversity does is get in the way of our progress, right?
A. Accidents. Car collisions, air strikes, grizzly and lion attacks, etc., all impact human lives negatively. These are legitimate, but small, concerns. A better understanding of wildlife behavior can minimize, but never eliminate, these accidents.

B. Crop and livestock damage. These amount to millions of dollars annually.
   1. Coyote and wolves kill livestock, but perhaps not as much as ranchers claim. Nonetheless, they do result in significant losses to some landowners.
   2. Ducks, geese, and cranes damage up to $30 million in grain crops each year.....that's the game part of wildlife...then there are all those pesky insects!
   3. Cosmetic solutions can be achieved through management of the wildlife, but more deeply rooted solutions come from changing agricultural philosophies and practices. We’ll talk more about this later, but I encourage some of you to pursue these controversial issues for your group presentation topics. For example, an examination of progressive solutions to wildlife-agriculture conflicts would make a fascinating topic, particularly if it focused on a case study or two.

C. Disease reservoirs.
   1. Zoonotic diseases transfer from wildlife animals to domestic animals and/or people.
      a. Rabies is a clear example.
      b. Brucellosis can be transferred from wild to domestic stock. ….its transfer from buffalo to cattle outside Yellowstone NP, and the political pressure to shoot some of the herd, would make another great discussion research topic.
      c. How serious are these concerns, and how can they be minimized? The best Solutions probably down to minimizing the interface, the juxtapositioning, of high density human/livestock and wildlife areas. Where urban centers abut high wildlife centers are often trouble….where high livestock pops commingle with high wild stock pops, etc.

D. Economic impediments. This is the most widespread, and poorly understood, negative value of wildlife.
   1. A basic tenet of economic thought is that a voluntary transaction takes place only when it is beneficial to both (human) parties involved. The clearing of forests for agriculture in the tropics, therefore, proceeds because it benefits the farmer (provides a means to make a living), and the consumer (provides produce).
   2. There are two problems with this view, stemming from an inadequate cost/benefit analysis in economics. The first is that intact ecosystems provide a wide array of ecological services/processes that are very beneficial for humans, but are poorly modeled by our economic theories. These services are call “ecological capital.” More on that in just a second.
   3. The second problem with this line of thought lies in its inability to account for what economists call externalities…that is, costs borne by humans outside the participants in the transaction. The clearing of forests may immediately benefit the farmer and the consumer, but it really sucks for the village downslope that receives the rapid mud erosion resulting from the loss of soil stability the forest used to provide. I encourage you to read and discuss a thought-provoking essay entitled, “The Tragedy of the Commons.”

Brief description of Tragedy of the Commons

II. Positive values of biodiversity can be best thought of by examining 4 classes of values (these comprise “ecological capital”) + 1 other value:
• Direct economic values
• Indirect economic values
• Option values
• Spiritual/aesthetic values

➢ The last “value” is ethical (value is in quotes because this differs from all the others in that the value is not a value for humans….but an intrinsic value of wildlife in itself).

A. Direct economic values. These are values assigned to those products of nature that are directly harvested and used by people. They can be further divided into consumptive use values (for goods that are consumed locally), and productive use values (for products that are sold in markets). Examples include fuelwood, meat, fur etc. Controversial because at best they involve humane killing and captivation; at worst, inhumane exploitation. Nonetheless, commercial values comprise a human-centered utility of wildlife, making their preservation prudent in human terms.

1. Consumptive use values. These are biodiversity goods that are consumed locally and do not appear in the national and international marketplaces.
   a. People living close to the land (as in many developing countries) often derive considerable portion of the goods they require for their livelihood from the environment around them, but because these goods are never bought or sold, they do not appear in the GDP of such countries.
   b. The reliance on local goods is surprising. For example, about 80% of the world's population still relies on traditional medicines from plants and animals as their primary source of medical treatment. Another major human requirement is protein, which many cultures obtain from wild game. In Botswana, 40% of the average person's protein intake is from wild game, in the Congo, 75%.
   c. Value can be assigned to these goods by considering that if rural people were unable to obtain them, as might be the case following environmental degradation, then their standard of living would decline, perhaps to the point of starvation.
   d. Implicit in this argument, is the assumption that environmental degradation is not automatically coupled with increased local wealth. For if it was, rural people could just buy the good previously provided by their environment. And perhaps those medicines would be more effective anyway? (studies have repeatedly shown that effectiveness of traditional medicines can be enhanced by purifying and concentrating the medicine)....Something to think about.....Just as anti-environmentalists can be criticized for thinking too narrowly and accepting conclusion consistent with their world view before thinking critically, so can environmentalists.....we always have to strive to think critically....
   e. One attempt to assign monetary value to these goods (and think critically about them) was made by Caldecott (1988) for wild pig meat in Malaysia. He estimated that the protein obtained by rural people would cost $40 million per year if bought from traditional markets. No environmental liquidation (even complete clear-cutting) could possibly generate such funds, so (in this case), environmental degradation would appear to lead to increased poverty and mal-nutrition. The value of biodiversity appeared to very significant, even when using economic models.
   f. Others have contested his estimate of $40 million.

2. Productive use values.
a. Productive use values are those assigned to products that are harvested from the wild and sold in commercial markets. Traditional economic models can be applied here.

b. The major productive goods of the world are: fuelwood and timber, fish and shellfish, medicinal plants, wild fruits and veggies, wild meat and skins, fibers, honey, etc.

c. These values are significant, even in industrial societies. In the US, 4.5% of the GDP depends directly on wild species. In developing countries with less industry, it is higher.

d. Timber is the biggest, contributing $120 billion in international trade per year. Many tropical countries are exporting large amounts of timber to pay foreign debts. Non-wood products of forests can be substantial, especially in tropics, and, if properly modeled and managed, can greatly exceed the long-term profits of managing land for timber. For example, in India, 63% of the foreign money earned from forests comes from fruits, gums, resins, rattans, etc. This provides strong economic incentive to maintain forest cover.

e. The greatest productive use value for many species lies in their ability to provide new genetic material for industry and agriculture. The continued genetic adaptation of crops is required to increase their yields and guard against resistant strains of insects, fungi, etc. Catastrophic failures of crops can often be linked to periods of low genetic variability: 1846 potato blight in Ireland, 1922 wheat failure in Soviet Union, and the 1984 outbreak of citrus canker in Florida. Continued alteration of crop genetics (naturally, through fertilization) from wild stock, can guard against this.

f. Wild species can also be used as biological control agents. In many cases, exotic, invasive, and economically damaging insect pests have been controlled by searching the pest species' original habitat for another species that limits its population. This control species can then be carefully introduced to control pest. Obviously, you're playing with fire here, but there are many success stories, which don't usually make headlines as much as failures. For example, the South American mealy bug was accidentally introduced to Africa, where it devastated cassava crops (a potato like veggie essential for Africans' culture and survival). After an intensive world-wide search, wildlife biologists found a tiny wasp in Paraguay, previously unknown to science, that parasitizes the mealy bug. It was brought to Africa, and resulting in quick control of the mealy bug. As mealy bug numbers fell, the wasp had little to feed on, so its numbers fell too. Both will likely remain in Africa as introduced species, but at low, regulated, population sizes.

g. Biodiversity is also a vastly important source of medicines. Over 75% of the leading 150 prescription drugs used in the US were originally derived from wild species. The biological communities of the world are continually being searched for new species that may be used to fight cancer and AIDS, etc. Government research institutes (especially in the tropics) and pharmaceutical companies are conducting the searches.

B. Indirect economic values. (non-consumptive)

1. These are values that can be assigned to aspects of biodiversity, such as environmental processes and ecotourism, that provide economic benefits without being harvested or destroyed during use.
2. Because they are not goods or services in the typical economic sense, they usually do not appear in statistics of national economies, such as the GDP. This is a major inadequacy of economics currently being debated and worked on by "green economists."
   a. The calculations are still preliminary, but they suggest the value of ecosystem services (e.g., clean air, water, etc.) is enormous, $32 trillion annually (Costanza et al. 1997 in Nature). This figures outweighs the global gross product ($18 trillion), so humanity appears very reliant on environmental integrity, even as determined by economic analyses.
   b. However, other estimates are much lower (Pimental et al. 1997 in BioScience), and many economists are in sharp disagreement about how these calculations should be done (Masood and Garwin 1998 in Nature)

3. Ecosystem productivity/stability.
   a. Energy on earth ultimately comes from the sun, and plants are the critical link that convert the sun’s energy to forms usable by humans (as plant tissue, food for animals, oil, etc.). They are the producers on earth. About 40% of the productivity of terrestrial environment is used directly or indirectly by people. Destruction of vegetation via deforestation, overgrazing, desertification, etc, results in lower productivity...which eventually trickles its way up to people.
   b. What about diversity and stability. This currently being debated and researched right now. Seems to sometimes be a correlation between stability and biodiversity. But is that because stable climates foster high biodiversity, or because high biodiversity ensures stability? Not sure yet…

4. Protection of water and soil. Biological communities, especially forests and wetlands, are of vital importance in maintaining water quality and buffering land from extremes of flood and drought. But is this biodiversity that offers such protection, or is it an intact functioning ecosystem, regardless of how many species it harbors???
   a. Plant foliage and dead leaves intercept rain and reduce its impact on the soil, where plant roots and soil organisms aerate the soil to make it more sponge-like, and stabilize it from running off under high water.
   b. Horror stories of increased flooding and mudslides from excessive deforestation are commonplace. India, Philippines, and Thailand have had flooding so badly downstream of timber harvests that locals have literally pled for forest protection. A clear-cut induced mud slide (near Stafford) prompted Julia Butterfly Hill to climb a redwood...and stay there.
   c. The need to protect clean water supplies in New York city prompted it to pay $1 billion to rural counties in upstream New York state counties to protect the forests around water reservoirs used for city water....to keep it clean. This was a good investment, because building water treatment plants to do the same thing would have cost $8-9 billion.

5. Regulation of climate. Plant communities are important moderators of local, regional, and global climates.
   a. At local level, plants respire and transpire water, provide shade and keep places cooler. If you ever drive down the central valley in the summer, stick your arm out the window as you past a green field...you can easily feel how much cooler the air is compared to an urban area of dry pasture.
b. At global level, plants are a "sink" CO₂, that is, the take in CO₂ (which contributes to global warming) and give off O₂, which does not. Remember we can’t gain or lose carbon on the Earth, but our actions can change where it is stored. Storing C as carbohydrates in plant tissue is environmentally beneficial, whereas storing as CO2 in atmosphere is damaging.

6. Waste disposal and nutrient retention. Wetlands are especially important in that their algae and fungi and plants break down and immobilize pollutants such as heavy metals, pesticides, and sewage. A good example of this is the New York Bight, a wetland area at the mouth of the Hudson river. It effectively cleans the sewage of 20 million people in the NYC metro area. Degrading this bight would have dire consequences on the city.

7. Species relationships. Because species are connected in intricate ways via the food web, many species that have no apparent immediate value are elevated in their importance because some other species of direct value is reliant upon them. There are hundreds of examples, perhaps the most elementary is the reliance of most species of trees on soil fungi for nitrification. Without soil fungi, trees would not grow. Recent diebacks and slow growth of trees in Europe may be a result of deleterious effects of acid rain not on the trees themselves, but on the soil fungi upon which the trees depend.

8. Recreation and ecotourism
   a. Consumptive recreation – hunting, fishing, plant collecting, etc. Bigger than you might think. In 1975, 20 million hunters spent half a billion days afield hunting game. The economic proceeds from these groups, and their positive influence of land acquisition for wildlife, is inarguable. Their philosophical influence on American attitudes to wildlife is arguable.
   b. Non-consumptive recreation – bird watching, nature photography, hiking? Ecotourism (non-consumptive is an exaggeration; we can talk more about this later). Huge. The single most popular hobby in America is nature appreciation, in some form. The economic impact, in terms of travel, equipment, and books, is nothing short of colossal.
   c. In places with international scenic significance, like Yellowstone Nat'l Park, the non-consumptive recreational value of the land dwarfs that of other local industries including timber harvest, farming, mining etc. Some argue that even sport hunting and fishing is "non-consumptive" because the amount of wild species extracted form the land relative to money spent on travel, lodging, equipment etc. is negligible. Also, much of that money goes directly back into adequately managing the populations for sport hunting/fishing.
   d. Tropical eco-tourism. Becoming a bigger industry every year. In several African countries, ecotourism is among the top three industries.
   e. With further ecotourism development, however, is danger. Tourist facilities can provide sanitized fantasy experiences, leaving visitors ignorant of the threats to biodiversity and the serious local social and environmental problems. Tourist facilities themselves can contribute to the degradation of sensitive areas.....becoming a concern in the United States, especially. A good topic for a research discussion....our National Parks....our National Paradox of loving them to death.
9. Educational and scientific values. This is straightforward, but under appreciated. Natural phenomena have value in their ability to increase human knowledge and enhance education.

10. Environmental monitors.
   a. Species that are particularly sensitive to chemical toxins can serve as an "early warning system" for monitoring the health of some aspect of the environment. The canary in the coal mine. Lichens are excellent indicators of atmospheric purity, for they obtain all their resources directly from air and water. Mollusks are excellent indicators of water quality, for they filter vast quantities of water to obtain the food at very lower concentrations within it.
   b. At a larger scale, the presence and health of larger species of vertebrates may indicate that an entire ecosystem is functioning well. So called "indicator species" can be good flags for "ecosystem health", a concept that has proven otherwise elusive. Indicator species tend to be specialized on a particular environment, sensitive populations whose number are closely allied to environmental conditions, non-migratory, and tend to be relatively long-lived. Good examples include the Northern Spotted Owl. Their presence and successful reproduction indicate a healthy, functional, mature forest.

C. Option values. The option value of a species is its potential to provide an economic benefit to human society at some point in the future. As the needs of society change, so must the methods of satisfying those needs.
   1. Two considerations here. First, this value does provide an economic incentive for protecting biodiversity....but it’s a weak one. "We should protect it not for what it is....but for what it may be one day."
   2. Second, who owns the development rights to the world's biodiversity? In the past, species were collected from wherever they occurred, often by corporations from the developed world (who paid their own way...it is all perfectly legal), who later brought the chemicals back to the states (say) and synthesized the chemical artificially. Increasingly, governments in developing nations are rightly demanding that a share of the profits from new products be returned to countries in which they were originally collected. Writing treaties and developing procedures to guarantee participation in this process will be a major diplomatic and economic challenge in the coming years.

D. Spiritual and aesthetic value that transcends economic value.
   1. Aesthetic. Most Americans will never see a wild polar bear, a resplendent quetzal, or a Komodo dragon….yet for many people there is considerable value in simply knowing they exist wild and free somewhere in the world. Thus, the inherent natural beauty and artistic appreciation of wildlife, its aesthetic value, is profound.
   2. Spiritual value. Lastly, do biodiversity and natural ecosystems contribute, in philosophical terms, to successful human life? Beyond aesthetics.... The existence of wildlife, and hence its preservation, provides a wellspring for intangibles such as discovery, ambition, and hope, which are critical for fulfilled human life. In short, wildlife enriches human life. In writer Wallace Stegner’s words, “. Many philosophers agree. "In wilderness is preservation of the world." HD Thoreau.
   3. Scientists are beginning to ask why (evolutionarily) this may be the case. “Biophilia”.

III. Ethics and wildlife.
Even though the methods of ecological economics are a positive development for conservation, they can also be viewed as signs of a willingness to accept the present world economic system as it is, with only minor changes. Given a current economic system in which millions of thousand of unique species disappear forever each year due to habitat destruction, we may ask, do we need to make minor changes, or major structural shifts in our thinking?

Regardless or economic/human value…these arguments call for the protection of all species.

A. Steward responsibility. Most often seen in religion. Nature was in some way created divinely, and we have a responsibility to act as its steward. Species are sacred. Jewish, Christian, and Islamic traditions share this thread.

B. Responsibility to future generations. Wildlife have some human value (by practical and/or spiritual arguments); therefore, their extinction leaves the world impoverished for future human generations. Chief quote.

C. Intrinsic value and interconnected species.

- All species have a right to exist, and they exert this “will” even if they are not sentient by the simple virtue of their production of young and evolutionary adaptation. The premature extinction of a species due to human activities is considered “supernatural”, and hence, unethical (much like the killing of another human). I often hear the argument that extinction is natural, and that we are species too, so if we drive another species toward extinction, it is inappropriate to call that “wrong.” But that argument can be used to justify ANY human behavior. So it has NO ability to discriminate between good and bad, appropriate and inappropriate, acceptable and unacceptable. Thus, this “law-of-nature” argument is rendered trivial and useless. Essentially, the intrinsic value argument calls for the extension of our awareness from ourselves, through ever increasing circles, to our kin, to our social groups, to our species (all races and sexes), to other species, and to entire ecosystems. OVERHEAD

Quote of the day:
"Biodiversity is the tool with which you can play the game of promoting global stability. But it also consists of the organisms that give wonder and beauty and joy to the world, and that provide the context in which we evolved."

Peter Raven, 1990