Ecology and Conservation: Humans in the Environment
Environment 201 Autumn 2005 James R. Karr

The goal is to aid students in discovering eight key points:

1. **Biotic impoverishment**, the progressive degradation of Earth's living systems (human and nonhuman), is now a primary threat to human and nonhuman communities.

2. **Degradation** as well as its **causes and consequences** cannot be understood without consideration of long **temporal** and extensive **spatial scales**.

3. **Ecology** (the science) and **ecological thinking** are vital to reversing long-term trends.

4. Broad **connections between human health and ecological health** are not adequately understood by and communicated among all segments of the human community.

5. **Improved ecological indicators** are needed to explicitly track the condition of **biological capital (human and nonhuman)**, the **sustaining wealth of the world**.

6. **Societal decision making** can only be well informed when the relationships among **ecological, social, and economic systems** are understood and when appropriate **indicators** of the condition of each system are employed to understand the consequences of human actions.

7. Both informed **decisions by individuals** and **comprehensive public policies** are needed to reverse centuries, even millennia, of ominous trends; those decisions and policies must contend with **spatial scales** extending from local to international and **temporal scales** ranging from election cycles to many human generations.

8. **Conservation** of living systems (human and nonhuman) is central to the future of humankind.

Overview: The Primary Lessons

1. Ecology is the science that seeks to understand relationships between organisms and their environments.

2. Formal definitions of ecology vary, placing emphasis on different contexts (e. g., interactions of organisms with one another and with their chemical and physical environment, distribution of plants and animals, flow of energy and cycling of nutrients in the biosphere).

3. Effective use of ecology in a process of ecological thinking involves integration with diverse disciplines (humanities, natural and social sciences, engineering, law and policy).

4. Conservation is the application of the principles of ecology to protect the parts and processes of living systems.

5. The Universe is very heterogeneous.

6. Earth is unusual in many respects: size of its sun; distance from sun; lack of nearby space debris; right size of planet; stable orbit; correct tilt on axis; nearby moon; presence of water, abundance of carbon and oxygen.

7. Life is likely in many places in the universe but complex metazoan life is rare, and advanced civilization likely unique.

8. Earth's biosphere is sum total of all places where organisms live, including vast areas of the lithosphere, the hydrosphere, and the atmosphere.

9. Earth’s complex biosphere is unusual and spatially and temporally heterogeneous (e.g., poles to equator; seasons) due to distribution of heat (energy) from the sun and availability of water.

10. The sun is, in effect, a giant engine that powers the winds, the water cycle, photosynthesis, and all animals, including humans.

11. The metabolism of living systems from individual plants, animal, and microorganisms to the “Earth’s metabolism” to the “industrial metabolism of human society depends on the supply of energy from the sun.

12. That heterogeneity produces diverse plant and animal assemblages referred to as biomes in land environments. (Same can be said for aquatic and marine environments although the exact details differ.)

13. Geographical ecology is the study of patterns in the distribution of species (kinds of organisms) and communities (assemblages of plants, animals, and microorganisms that live in a place).

14. Each biome (tundra, coniferous forest, deciduous forest, grassland, savanna, chaparral, desert, tropical rain forest) has characteristic climate and soils, a biota finely tuned to survive in those conditions, and a characteristic geographical distribution.

15. Some species have very narrow distributional ranges while others are widely distributed; humans have spread in the last 50,000 years to occupy directly or indirectly the entire planet.

16. Major advances in humans came about 50,000 years ago with developments in technology and art (the Great Leap Forward) and again beginning about 15,000 years ago with the advent of agriculture (Second Leap Forward).

17. Domestication, a major component of agricultural advance, is the selective breeding by humans that genetically modifies a species to make it more useful to humans.

18. Domestication of animals, which began at least 15,000 years ago, helped to buffer humans against starvation.

19. Domestication occurred in a select set of areas on Earth and at varying times; the precise places were probably defined by the presence of species suitable for any of a variety of reasons for domestication.

20. The major areas of domestication include the Middle East (Fertile Crescent), China, MesoAmerica, South America, Sahel/West Africa, Ethiopia, and New Guinea.

21. Agriculture and the settled lifestyle it entailed, involved trade offs between increased **quantities** of humans and lower **quality** of life for individuals.

22. Domestication led to eating livestock and crops, yielded food surpluses, and a cascade of events: growing population, sedentary lifestyle, political centralization, social stratification, economic complexity, technological innovation, and a variety of new human diseases.

23. The major change since domestication is the scale of the human endeavor: rapidly expanding human numbers, the spread of human influence to all corners of the earth, and human industrial metabolism.

24. The temporary, rotating, footprints of patch disturbers have been replaced by the permanent and increasing footprint of settled peoples.

25. Settled societies allowed the accumulation of goods, increased consumption, and provided incentives to devise more powerful technologies for meeting those desires.

26. Urbanization allowed increased specialization of skills and social roles, thus stratification of societies into rulers and ruled; as a result, decision makers are often buffered from knowledge and the consequences of their choices' for people and for the natural world.

27. The evolution of different human cultures (called natural histories in other species) in different regions reflects the heterogeneity of Earth environments.

28. Human have become the dominant species on Earth due to the blossoming of our intellect and its expression through culture and technology.

29. A crucial component of that development is our ability to control fire and thereby capture energy from diverse sources.

30. The seeds of modern environmental and social challenges can be seen in the experiences (the history) of human societies in all regions of the world.

31. Ecology is a relatively new science that deals with the distribution of plants and animals, the interactions of organisms with one another and with their chemical and physical environment, and with the flow of energy and cycling of nutrients in the biosphere.

32. Changes in populations of species result from births and deaths as well as immigration and emigration.

33. Simplistic models of the growth of populations emphasize exponential and logistic growth.

34. More realistic conceptions of population dynamics incorporate age-specific birth and death (survival) rates, population age structure, variation in carrying capacity, interactions with other species, and the dynamics of metapopulations. The growth of a species' population is limited by the nature of diverse resources available in that organism's environment.

35. Only the human species has been able to sustain exponential population growth, even super-exponential growth in recent times, over sustained periods, but this growth cannot last for much longer. To quote economist Kenneth Boulding, "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist."

36. Fragmentation of populations due to the actions of humans is a major threat to many species and a primary focus of conservation biology.

37. Although most emphasis has been placed on the survival of the fittest (competition among organisms), interactions among organisms may be negative, positive, or neutral.

38. The niche of a species is the functional role, job, or occupation of a species in a biotic community or ecosystem.

39. Coevolution is the joint evolution of one species with another species through reciprocal selective pressures. Predators coevolve with prey, flowers with pollinators, parasites or diseases with their hosts, and so on.

40. Several key factors govern what species are present at a place: climate and geographic conditions, available resources, adaptive traits of the species, interactions with other species, and history.

41. All organisms require a supply of energy and nutrients, the former flows through the system and is dissipated as heat, the latter is continually cycled with different reservoirs and cycling rates.

42. The efficiency of energy transfers from one trophic level to another is roughly 10%.

43. Global biogeochemical cycles (e.g., water, carbon, nitrogen, and phosphorus) involve movement of those materials from the environment to organisms and back.

44. Each "elemental" cycle has its own inorganic or abiotic "reservoir": carbon – atmosphere; nitrogen – atmosphere; phosphorus – rocks.

45. The nitrogen cycle is especially complex with the conversion of inorganic nitrogen to organic form, largely by nitrogen fixing bacteria. The reverse (denitrification) is accomplished by bacteria and fungi breaking down nitrogen-containing wastes.

46. In recent times, human activities have significantly altered these cycles locally and globally by burning fossil fuels (carbon), anthropogenic nitrogen-fixation (Haber-Bosch process), and use of high phosphorus detergents.

47. In human systems, energy is used much less efficiently than in natural systems (largely due to availability of cheap fossil fuels) and nutrients and other materials have a one-way path, often ending up as waste instead of being continually recycled through living systems.

48. Natural ecosystems when compared to human-dominated ecosystems tend to be more complex and stable with more species and more interactions, run on energy from sunlight rather than nonrenewable energy such as fossil fuels, recycle nutrients rather than lose nutrients, purify and store water rather than pollute and shed water, and maintain more stable populations of resident species.

49. Ecology is richest as a science and most useful to resolve challenges faced by human society when the many approaches and dimensions of ecological systems are explored in an integrative fashion. Two study systems illustrate this point:
    a. lyme disease in New England forest: involves interactions of humans, deer, oaks and their acorns, mice, gypsy moth, ticks, the microorganism that causes lyme disease, and weather conditions.
    b. wolf extermination and their later reintroduction by humans in Yellowstone National Park: involves interactions of elk, beaver, coyote, birds, fish, willow, cottonwood, hydrology, and stream channels.

50. Biodiversity patterns provide an important window on the evolution of life on earth. These include latitudinal gradients of diversity (generally higher in tropical regions and lower in high-latitude areas) and changes in diversity on isolated islands (higher on large islands than distant islands, higher on islands near continents than more remote islands)

51. The equilibrium number of species on an island is a primarily product of the balance between extinction and colonization rates.

52. Human societies on South Pacific Islands illustrate some of the basic principles of ecology and natural history evolution. Because those islands vary in climate, geological type, availability of marine resources, island area, terrain fragmentation, and island isolation, there is considerable variation among human societies occupying those islands. These include differences in subsistence modes, economic systems, social organization, political organization, and material culture.

53. Population densities also vary from $5/mi^2$ to $1,000/mi^2$, illustrating massive variation in carrying capacity as a result of the interaction of natural environment and human culture.

54. A recent analysis shows that deforestation, which is known to vary among the South Pacific islands, is more severe on dry than wet islands, cold high-latitude than warm equatorial islands, old volcanic than young volcanic islands, islands without aerial ash fallout from Central Asia than islands with it, low islands than high islands, islands without makatea (uplifted razor-like coral) than islands without makatea, remote islands than islands with near neighbors, and small than big islands.

55. These deforestation patterns demonstrate the importance of temperature and rainfall, soils, disturbance patterns, and island biogeography as determinants of probability of deforestation.

56. All organisms change their environment in some way; we refer to those that are most influential as “ecosystem engineers.”

57. From the early photosynthetic prokaryotes to modern humans the Earth has been changed in many ways by the actions of “ecosystem engineers.”

58. Humans are the ultimate ecosystem engineers; the ecological footprint of human society, due largely to our “industrial metabolism,” is unprecedented for one species. We dominate the earth's ecosystems everywhere.

59. That footprint is the product of human reproductive and consumptive behavior, including the challenges created by waste accumulated as a result of consumption.

60. Footprints vary among peoples and cultures, nations and regions, and over time.

61. The footprint of prosperous cities' consumption and waste disposal can extend around the world.

62. Humans feed at lower trophic levels in terrestrial than marine systems.

63. An audit of Earth shows that humans now consume 40% of terrestrial production, 60% of available freshwater, and 35% of the ocean’s continental shelf production each year.

64. Optimists might conclude that problems are not obvious, for example, because 60% of terrestrial production remains available for use by humans. Pessimists conclude that we are in trouble because a single species is so dominant on Earth. The next five weeks will be used to explore how you might decide for yourself whether the optimists or the pessimists are correct.

65. Our audit of the Earth suggested that humans currently consume one third or more of the annual production of living systems that occupy terrestrial or continental shelf regions.

66. Optimists see the 60% that remains as resources to be captured by humans and pessimists conclude that we are in serious trouble. How can the responsible student or citizen decide which side to believe?

67. The role of a citizen is, like the role of the scientist or scholar, to collect and evaluate relevant evidence and to come to an informed decision.

68. A major consequence of the human footprint is biotic impoverishment, the systematic reduction in the Earth’s ability to support living systems.

69. The many faces of biotic impoverishment include three major classes of degradation of the fabric of life: indirect depletion of living systems through changes in Earth's physical and chemical systems; direct depletion of nonhuman living systems, and direct depletion of human systems.

70. The seeds of modern environmental and social challenges can be seen in the experiences (the history) of human societies in all regions of the world.

71. The twentieth century has been a time of especially rapid increase in the industrial metabolism of human society and thus pressure on Earth’s living systems.

72. As human reproductive and consumptive behavior increased in the last century, societies more frequently encountered linkages among the many faces of biotic impoverishment. For example, declining availability of food and increased incidence of disease are worsened when injustices based on race or economic standing limit opportunities for major segments of society. These in turn lead to social unrest and political instability.

73. Human populations are not immune to demographic collapse. The declines after the fall of Roman, Han, and Mayan empires or more modest societies such as Easter Island attest to our vulnerability to human-induced collapse.

74. The Black Death took a third of Europe's population within five years of its arrival; the influenza of 1919 killed between 20 and 40 million people. If we find a vaccine for HIV/AIDS today, the death toll will still be at least 60 million. We are, by nature and like all species, vulnerable to natural calamities. Unwise human actions that yield the many faces of biotic impoverishment increase our vulnerability.

75. Collapses of past societies can often be tied to the influence of one or more of the following five factors: damages that people inadvertently inflict on their environment; natural variation in local and regional climatic conditions; the presence of hostile neighbors, decreased support of friendly neighbors; and, of major importance, a society's response to problems that arise.

76. The people of Tikopia, a small Pacific Island, demonstrated an ability to make tough decisions to prevent a population collapse.

77. Although ecology (the science) is rapidly evolving, the core principles of ecological thinking remain much the same today as they were articulated by cultures as far back as 5000 years ago.

78. The major change since then is the scale of the human endeavor: rapidly expanding human numbers, the spread of human influence to all corners of the earth, and the scale of human industrial metabolism.

79. Myth-making is a universal property of human societies and plays a vital role in every culture. The myth of "sustainability through growth" is the dominant myth at the beginning of the 21st century.

80. Causes of decline of ancient civilizations around the world have long been debated. Within the complex causes, recent scholarship increasingly points to the importance of environmental factors.

81. Past experience shows that if we behave as we evolved to do and we do nothing to regulate or moderate ourselves, the ecosystems upon which our civilizations depend will collapse. For the first time ever, the effects, consequences, and aftermath will be felt on a global scale.

82. Two factors, fragmentation of knowledge and a narrow conception of indicators needed to track the well being of society, are the cornerstones of much modern policy. They yield misleading results, giving us permission to continue current destructive and unsustainable trends.

83. Many people are working to improve the range and integration of indicators with special emphasis on indicators to more accurately reflect social and environmental consequences of human actions.

84. An important step in that process will be to abandon the view that a Venn diagram depicts the interactions of ecological, social, and economic systems. A more appropriate representation is as a layer cake with the economic system being the frosting on a two-layer cake including the social system and its supporting bottom layer, the ecological system.

85. Economic indicators provide useful information for our society; progress and improvements in the formulation of these indicators can only improve our decision-making ability.

86. When presumed "externalities" are ignored, prices do not fully account for the consequences of a decision.

87. To ensure the most beneficial use of our time, labor, and physical, biological, and natural capital, all consequences of an action need to be taken into account.

88. Ecological understanding leads us to recognize that our planet develops over time without growing and our economy must adapt a similar pattern of development without throughput growth.

89. Social indicators that reflect human well-being are being developed and used by organizations and institutions throughout the world from local and national to regional and global scales.

90. Ecosystem services provide many of the essential foundations of life for human society. Ignoring the impact of our decisions on them often leads to negative outcomes.

91. Development of ecological indicators has advanced in recent years with efforts to measure the relationships between ecological, social, and economic systems (e.g., monetary valuation of ecological goods and services, ecological footprint analysis) as well as approaches to measure the status of the productive capacity and biodiversity of nonhuman living systems. Proper measurement of the latter will indicate the status of the principle in Earth's natural capital.

92. An understanding of the relationships between human health and ecological health is essential to the future of human society.

93. History shows society's ability to respond to changing health challenges. Protecting ecological health is a crucial dimension of the new wave of health challenges.

94. Health challenges faced by human society have involved four major transitions in the last 10,000 years: transfer of animal diseases to human through domestication; the migration of those diseases through human populations in Eurasia (biblical epidemics, black plague); transfer of those diseases to the Americas, South Africa, and Australia; and the recession of many diseases and emergence of new diseases in the past 200 years.

95. The solution of health problems—human or ecological—involves a five-step process: awareness that the problem exists; understanding its cause; ability to control the cause; sense of values that the problem matters, and political will to conquer the threat. Efforts to protect ecological health have not yet advanced to the last stages of this sequence.

96. Application of the insights of Darwinian medicine and traditional ecological knowledge (in contrast to western medicine) is crucial to dealing with current and future health challenges—both human and ecological.

97. The world's oceans are under severe stress with most major fisheries either depleted or over-exploited.

98. Overfishing of most large species (cod, swordfish, tuna) has taken them to the verge of collapse (or beyond) in the last decade.

99. Aquaculture (farming fish) is currently not a sustainable solution to the fisheries crisis because most farmed fish are carnivorous; feeding fish meal to fish results in a massive reduction in fish biomass available for human consumption and fishing pressure is not reduced.

100. In *Empty Oceans, Empty Nets* we saw that what young fishermen believed to be a "good catch" of Atlantic swordfish was not a "good catch" 50 years earlier; a discrepancy in perception called "shifting baseline."

101. Depletion of the world's ocean fish begins with harvest of the top carnivores and proceeds through sequences of smaller and smaller, and less valuable, fish at lower trophic levels, a phenomenon referred to as "fishing down the food web."

102. Remediation efforts and strict regulations in some areas (e.g., Alaska) have permitted some stocks to recover, illustrating that recovery and sustainable fisheries may be possible.

103. Human perceptions about and interactions with the environment have evelved with time.

104. Early evidence of environmental perceptions can be seen in the cosmologies of indigenous cultures throughout the world. Pacific Northwest natives, for example, treated all parts of the earth as equal members of a community in a "gift economy."

105. From Mesopotamia to ancient Europe (Plato), from the golden age of global exploration (von Humboldt, Thoreau, Marsh) to modern America (Leopold, Berry), much has been said about the human place in nature and the consequences of unwise human actions.

106. Looking back 150 years, we see four major waves in the development of environmental thinking in the United States: genesis of conservation (1850-1960); imperative of containment (1962-1980); period of co-optation (1980-early 1990s); and emerging understanding of interdependence (early 1990s to present). The Earth Charter is an illustration of the latter.

107. Ecological thinking with conservation and preservation as goals will be crucial ingredients of human actions in the 21st century.

108. The Earth Charter is evidence of widespread recognition of these issues and of a concerted action to invoke ecological thinking and communicate through a Declaration of Interdependence and Mutual (or Shared) Responsibility.

109. Every human achievement has come at an environmental price. We used to learn of the impacts only retrospectively. Tools such as footprint analysis and scenario planning allow us to anticipate environmental costs and to make more informed trade offs.

110. Tools such as the Earth Charter and the CERES Principles as well as the processes they suggest allow us to weigh the health of populations and ecosystems, both human and nonhuman, as well as ethical dimensions of policy decisions.

111. Humans can be passive passengers on a rapidly changing earth, accepting the effects, consequences, and aftermath of human actions. Alternatively, humans can behave not as helpless passengers but as active participants working to define the human future. To do so requires thinking on multiple spatial and temporal scales and the incorporation of ecological thinking into the design of human systems.

112. The actions we take individually and as regional, national, and global societies can yield vastly different outcomes. The increasing abdication of oversight roles by most levels of government makes the role of citizens and civil society ever more crucial.

113. The actual results of doing nothing are hard to predict, but they will likely include increasing disparities in the well-being of diverse segments of the human community, increased war among fortress states over resources, an increasingly toxic biosphere, catastrophic collapse of human populations, and an environment dominated by humans and highly adaptable human commensals, such as pigeons, cockroaches, crabgrass, rats, flies, sparrows, *E. coli*, cattle, pigs, dogs, and cats.

114. At the same time, many of the plants, animals, and human cultures of the land and sea that most conspicuously invest the earth with grace, delight, beauty, and vitality will be relegated to reserves or zoos, at best, or extinction, at worst. In short, inescapable biotic impoverishment on a global scale is a likely result and at the limit Earth may no longer be suitable for human living systems.

115. The most overlooked ethical dimensions of current policymaking are the consequences and aftermath for generations not yet born.

116. In the words of Klaus Toepfer, Executive Director of the U.N. Environment Program, "The challenge of this new century is to extend the economic progress of the last 50 years, while halting the ecological decline -- a sick planet will, sooner or later, lead to a faltering economy."

117. Rising to the occasion presents an unprecedented intellectual, political, and moral challenge, but it is not impossible. The words of Edward O. Wilson provide solace: “There can be no purpose more inspiriting than to begin the age of restoration, reweaving the wondrous diversity of life that still surrounds us.”

118. In the end, humans can bend the laws of nature, but they cannot be broken over the long term. Since the beginning of life on Earth, all species have been subject to one immutable law, "Nature bats last."