Appendix 6.1

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1 Identifying human elements in needed management

To apply systemic management, the tenets listed in Chapter 1 (Christensen *et al.* 1986, Fowler 2003, Fowler and Hobbs 2002, Fowler *et al.* 1999, Holt and Talbot 1978, Mangel *et al.* 1996, McCormick 1999; see also Appendix 4.3) cannot be ignored. The principles behind these tenets are clear and their requirements are to be fulfilled—simultaneously, consistently, and fully. No matter what form of management is being used, problems are to be identified through assessment, causes are to be ascribed (especially potential human contributions), and options for action identified.

In systemic management, frequency distributions (patterns) revealing abnormalities would be developed, whether they expose problems over which we have no control, or related problems over which we do have a measure of control (ourselves). The management questions will always be questions regarding how humans can fit in rather than how to make already overtaxed systems meet unrealistic human needs. The complexity to be accounted for would simultaneously involve individuals, species, ecosystems, and the biosphere, because none can be ignored. The identification of problems and tracing their origins to human contributions where we can take action are processes exemplified in the literature as reviewed below.

At the ecosystem level, changes observed are often ascribed to humans activities (Appendix 4.2) and emphasize the need to manage differently. Species are going extinct as has been the case over geological history owing to dynamics such as climate change, plate tectonics, or bolide impact with the earth (e.g., Raup 1989). Now, current extinction rates are arguably abnormal. Whether or not they are abnormal, they are being compared to mass extinction events that have occurred over geological history (e.g., Brown 1995, Diamond 1984b, 1989, Knoll 1984, Raup 1984, Raven and Cracraft 1999, Simberloff 1986b, Wilson 1985a,b). Loss of forests and grasslands are seen as responses to human influence. Reduced geographic ranges, increased abundance among pests, and problems related to diseases, parasites, and other micropredators are often seen as anthropogenic, as are declines in body size and trophic level, and increases in population variation. The observed changes may well represent abnormality for these ecosystems (e.g., MEA 2005a,b, Turner *et al.* 1990, Woodwell 1990a, World Conservation Monitoring Centre 1992).

In terms of human values, the benefits to humans of such change are usually interpreted as negative impacts on ecosystems. The impacts on ecosystems are often actively sought as a means of meeting short-term, local, or individual human needs. These include the production and distribution of agricultural products (especially food for humans, often locally in surplus), and space for living and transportation of the current population of humans. Risks, as we evaluate them, are exemplified by loss of goods and services, and the effects of pests and parasites in altered ecosystems, especially in the long term. These entail not only the easily recognized negative (in human value systems) effects of starvation, pain, death, and any resulting social disruption. However, they also involve the real risk of extinction—not only that which we observe among other species, but also that of our own. Over 99%

of all other species have gone extinct and there is little reason to expect that humans are different in this regard (Boulter 2002), especially in view of a history of human societies that have suffered extinction or near-extinction (Brown 1995, Catton 1980, Costanza *et al.* 2007, Diamond 2004, Lollar 1991, Whitmore 1980). Knowledge of the risks and how we may be increasing them is important (even if only to emphasize that such risks are accounted for in the integrative nature of natural patterns). Through regulation to avoid abnormality for our species, the tradeoffs among various risks are dealt with to achieve as much sustainability as possible for all systems involved.

There are costs, both as changes scientists observe and as problems identified in human value systems. These are incurred in both modifying ecosystems and then in maintaining them in modified form (Allen and Hoekstra 1992, Pimentel *et al.* 1993)—resisting the homeostatic forces of such systems. Some of these costs are documented by Pimentel *et al.* (1992). Pest control, for example, is a form of population level management that attempts to maintain an ecosystem state necessary for agricultural monocultures. The manufacture and application of pesticides is costly ($20 billion/yr worldwide in 1990; Pimentel *et al.* 1993). It is estimated that more direct costs from the effects of pesticides include 20,000 human deaths annually worldwide. Associated human health problems include mental impairment and immune dysfunction, a problem that extends to domestic livestock. Pesticides destroy other nontarget species including natural predators and parasites of the target pests and species of more direct benefit to humans such as honey bees and other pollinating insects of importance to food production (Perkins 1982). Also affected are aquatic systems and associated organisms.

Micropredators and microherbivores that use humans and their resource species as hosts (or as prey) evolve antibiotic and pesticide resistant strains (Garrett 1994, Georghiou 1990). Ecosystems that have been modified react over evolutionary time scales (periods that may be only a few years or even months for short-lived species) to produce changes, some of which will be forms that are more difficult to control resulting in greater costs in human life, energy, and effort. The genetic effects of our harvest and agricultural production of resources have unintended consequences, most of which have yet to be documented, and many of which will remain unknown.

Increased virulence can be expected to evolve in pests associated with monocultures of agricultural species (Farnworth and Golley 1974). Thus, as the human species itself becomes more of a monoculture through increasing density, especially in cities, it is not surprising to see increasingly challenging problems caused by diseases (Garrett 1994) and the threat of more (Webster and Walker 2003). More than a thousand species prey on humans and will undergo evolutionary modifications some of which will involve increased impact (Table 6.3). In addition, there are numerous species capable of attacking humans that occur (yet to be identified or discovered) in the ecosystems of the world with which humans are increasingly coming into contact (and modifying). As with other species in this regard, the human relationship with ecosystems entails at least two components. One is phenotypic (ecological mechanics) wherein disease organisms limit human numbers. The other is genetic with at least two components: other species and humans. Disease species evolve to exhibit greater effects (evolutionary processes raising risks of dramatic human population declines as those experienced in the past and even extinction). Diseases are also involved in the process of natural selection; humans without genetically resistant immune systems are selectively more vulnerable.

Increasing incidence of diseases as the human population increases is already being noted. Human diseases that have recently challenged epidemiologists includes Legionnaires disease, Lyme disease, Bengal cholera, *E. coli* O157, Hantavirus, Ebola virus, *Cryptospiridium* (intestinal parasite), streptococcal bacteria, new strains or multidrug resistant forms of *Staphylococcus aureus* (MRSA), filovirus (Africa, Philippines, Germany), west Nile virus, tuberculosis, and the new strains of diseases, like flu and severe acute respiratory syndrome, that appear each year (see Curson 1989, Dowdle 1993, Garrett 1994, Gibbons 1993, McMichael 1993, Morse 1993a,b,c, Webster and Walker 2003). Over the course of history, diseases have dramatically

reduced various populations of humans, some apparently to extinction.[1] Today, the emergence of new diseases through mutations, sharing genes for antibiotic resistance or virulence (e.g., by way of plasmid transfer and conjugation among bacteria), and chronic exposure to antibiotics is a source of serious concern to epidemiologists in light of human population densities, mobility, and compromised immune systems (Garrett 1994, Webster and Walker 2003). Mutation resulting in AIDS, Ebola, or other virus capable of being transmitted by minimal physical contact or in aerosol media (sneezing, etc.) could produce effects at least as dramatic as past epidemics. Evolution of an extremely virulent influenza virus (much as happened during World War I, Garrett 1994) could do likewise.[2]

Increased contact with pre-existing species of diseases and parasites is related to increasing population size and resulting expansion of geographic range. The evolution of new strains is also not unusual and is expected more often in species with short generation times. If new strains are arising at increasing rates, however, a different ecosystem-level change is in effect. The increasing numbers of treatment resistant strains and microorganism-based diseases may represent such a possibility (Garrett 1994). Their numbers and abilities to develop new forms threaten to overwhelm existing disease control efforts and certainly to increase the monetary costs of such "control" (Garrett 1994, Webster and Walker 2003).

Significant changes in the world's ecosystems are not only posing problems for humans, both as individuals and as a species, but are also problems for other species. Nearly all scientific evaluations of the current state of the world's ecosystems express concern regarding observed changes (e.g., MEA 2005a,b, Turner *et al.* 1990, Union of Concerned Scientists 1992, Woodwell 1990a, World Conservation Monitoring Centre 1992). There is motivation for identifying the causes of the changes observed in the world's ecosystems—specifically the human contributions wherein we have a modicum of control.

One of the main contributors to observed ecosystem changes is, to most people, obvious: humans.[3] Forests, grasslands, and steppes are modified for agricultural purposes by humans. Deforestation, overharvesting commercial fisheries, pollution, habitat destruction, and introduction of exotic species (especially pest species), are primarily human activities. The acidification of marine waters, global warming, acid rain, and human-related changes in ozone layers, in their impact on ecosystems are human-caused changes in the physical environment. Many changes in the marine environment are attributable to humans (Halpern *et al.* 2008) through overfishing, CO_2 production, and pollution. Housing, roads, airports, cities, businesses, factories, irrigation canals, and other such man-made structures displace other species, reduce their geographic ranges and population sizes, and introduce gaps in their habitat and distribution.

Coe (1980) suggests that man affects "…more in Africa than animal distribution and abundance; he is disrupting and destroying entire habitats. ….It would be foolhardy to suggest that man has been solely responsible for the formation of the savannah, but it would not seem unreasonable to suggest that he has been the primary agency in the erosion of the forest and dense woodland margins and, therefore, has been a primary force in the extension of the Sahel zone". Andrewartha and Birch (1984) indicate that "…cause for extinctions seems to be the destruction of habitat by burgeoning populations of *Homo sapiens*". Allen and Hoekstra (1992) say that "The nonequilibrial nature of the modern world is something that emerges when we try to describe ecological systems in terms of the old parts of the biosphere that existed before the human population explosion…management itself explicitly holds the system away from equilibrium".

Most human activities (i.e., consumption, waste production, occupation of space) are natural functions in any ecosystem as for all species. The problem is not the mere presence and activities of the human species. The problem is the abnormal magnitude of so many of these processes and, unavoidably, their effects. As a species, humans *are* (and human values maintain that we should remain) a natural part of ecosystem. This is a requisite of Management Tenet 1; but this tenet is not basis for ignoring Management Tenet 5—being an abnormal part is a problem. The magnitude of impacts are important to address,[4] and cannot be dealt with

independently of the population issue. As Ehrlich and Ehrlich (1990) and others[5] have stressed, the magnitude of human impact includes the effects of: 1) human numbers and 2) the extent of per capita contributions. Both species- and individual-level issues are involved.

Life style, consumption rates, and technology contribute to determining the extent to which humans exert influence on their environments. Consumption is not alone; production of chemicals, pollutants, CO_2, and waste are also involved but do not complete the list of such factors. Technology entails the expression of human tool-using capacities supported by energy, primarily from hydroelectrical sources, petroleum, and coal.[6] Technology is not related simply to population numbers, but it would seem that certain intermediate population levels might support more per capita technology than either very small or very large ones.[7] Regardless of the technological magnification, the more humans, the greater the total impact. The impact of simple numbers is increased by per capita influence in cultures with technology. Again, both the size of the human population and per capita elements are important.

The concept that the human population may be too large and is one major contributing factor in environmental deterioration is nothing new in the minds of most scientists (Appendix 6.2) nor over human history (Costanza *et al.* 2007, Redman 1999). A variety of scientific organizations have published resolutions identifying the size of the human population as a basic problem. In 1970, for example, the American Society of Mammalogists (Am. Soc. Mamm. 1970) published a "Resolution on Population Growth". In 1960, and again in 1991, the American Association for the Advancement of Science (AAAS) passed resolutions regarding overpopulation. The 1991 resolution states "…growth of the human population contributes directly to human suffering throughout the planet, impedes sustainable economic development, increases international tensions, and exacerbates environmental degradation that endangers the survival of the human and many other species…" (Lollar 1991). The Union of Concerned Scientists (1992) published a warning to humanity regarding the effects of overpopulation (Ehrlich and Daily 1993). Calls for international response to the problem of overpopulation have been generated jointly by a variety of conservation associations, environmental organizations, and more specialized groups long concerned about the issue of overpopulation (Alper 1991).

The examples of abnormality in this chapter include population size as one issue for management. Systemic management would not be complete without taking action that results in population reduction, although doing so directly may be less advisable, from a systemic perspective, than letting the systems of which we are a part function so as to result in a reduction. Similar standards would apply if we were concerned about underpopulation and the risk of extinction from too few individuals.

Notes

1. "McNeill's law" refers to the disease facilitated spread of imperialistic peoples (Crosby 1986). Diseases such as smallpox, measles, typhus, scarlet fever, and venereal diseases reduced native populations to such low levels that there was little resistance to occupation of their lands by explorers. The Guanches of the Canary Islands appear to have been driven to extinction by imported diseases after their population increased beyond the capacity of the land to support them. Another example of such an extinction may have been the Arawaks of the West Indies. Other reductions in human populations have resulted from epidemics of endemic diseases. Black Death, a plague, may have killed one-third of the population of Europe during the mid-1300s, with death rates highest in crowded cities (Crosby 1986, Garrett 1994). In Norway and Iceland, two-thirds of the population may have died. The population of China declined by nearly 50% (see also, Catton 1980, Costanza 1995, Diamond 1986, Ehrenfeld 1993, Ponting 1991, Tainter 1988, and Yoffee and Cowgill 1988).

2. Perhaps of more concern is the risk that such things will happen by purposeful human design in biological warfare (or bio-terrorism exemplified in a number of novels published in the 1990s, and real-world events witnessed in the early part of the 21st century).

3. If there is any doubt concerning the impact attributable to humans, a reading of many of the references found in the bibliography of this book should be convincing (e.g., the appendices of this chapter, Appendix 4.2; Andrewartha and Birch 1984, Arizpe *et al.* 1994, Bloom

1995, Brown 1995, Christensen *et al.* 1996, Coe 1980, Diamond 1984b, 1989, Diamond and Case 1986, Ehrlich 1986, Ehrlich and Ehrlich 1981, Ehrlich and Wilson 1991, Eldredge 1991, Freedman 1989, Gibbons 1993, Green and Sussman 1990, Gregg 1955, Karr 1994, Law *et al.* 1993, Lawton and May 1995, Mark and McSweeney 1990, Martin 1986, McMichael 1993, Meffe 1994, Meyer and Turner 1994, Owen-Smith 1988, Pimentel *et al.* 1992, Pimm 1991, Pimm *et al.* 1995, Policansky 1993a, Ponting 1991, Postel 1994, Potts and Behrensmeyer 1992, Rapport *et al.* 1985, Singh 1995, Sisk *et al.* 1994, Skole *et al.* 1994, Southwick 1985, Specht 1990, Trotter and McCulloch 1984, Turner *et al.* 1990, Union of Concerned Scientists 1992, Vitousek 1994, Woodwell 1990a, World Conservation Monitoring Centre 1992).

4. An analogy that may be useful here is that of an individual being a natural member of a family. Any individual born into a family is a natural member. If that individual murders the rest of the family, the magnitude of his or her actions and their effects are abnormal in regard to sustainable participation within the family.

5. Numerous works make repeated reference to the $I = PAT$ of Ehrlich and Holdren (1974) in which I is the impact, P is the population, and AT is the per capita amplification of individual impact through affluence (A) and technology (T). See, for example, Kummer and Turner (1994), Mangel *et al.* (1996), and Smith (1995). Note that this both oversimplifies and underestimates the problem, at least in most cases, as there are a variety of dimensions over which impact can be measured and one, human caused extinction rates, shows evidence of being heavily non-linear (Appendix 6.6).

6. In the vein of selective extinction and speciation (Chapter 2) it is important to note that natural gas, petroleum, and coal are the remains of extinct species. Dependency on a species with high extinction risk is one thing, dependency on species that are already extinct is yet another. Other sources of energy, such as solar energy and hydroelectric power, are sources from the abiotic environment that can be used in ecosystem modification and maintenance that is not limited by the capacity of humans to ingest and undertake muscular work. This is a limit that other species experience in not having machines at their disposal and one of the major contributing factors to the structure and functioning of ecosystems (Fig. 1.4). For the most part, using sources of energy other than energy that is ingested, is highly abnormal for mammalian species of our body size especially when such sources involve nuclear energy.

7. For example, a human population of 500 individuals would, as individuals, spend most of their lives ensuring that they meet their basic needs (food and shelter). Little latitude would exist in such a population for specialization (e.g., to run computers, fly airplanes, manage fisheries, train physicians, publish books, administer universities, build satellites, construct solar energy collectors, or drill oil wells). To the extent that these relationships are more general, then, the per capita influence humans are capable of exerting shows an increasing relationship to population size. (Note that populations such as that of China have not realized the potential for per capita influence that have materialized in other countries.) There must be a maximum to this relationship beyond which human endeavor is increasingly channeled to deal with the negative impacts of excessive population (problems associated with physical and mental health, social upheaval and unrest, conflict over resource utilization, food production and distribution, and fighting diseases and parasites).

References

Allen, T.F.H. and T.W. Hoekstra. 1992. *Toward a unified ecology.* Columbia University Press, New York, NY.

Alper, J. 1991. Environmentalists: ban the (population) bomb. *Science* 252: 1247.

American Society of Mammologists. 1970. Resolution on population growth. Journal of *Mammalogy* 51: 856.

Andrewartha, H.G., and L.C. Birch. 1984. *The ecological web: more on the distribution and abundance of animals.* University of Chicago Press, Chicago, IL.

Arizpe, L., M.P. Stone, and D.C. Major (eds). 1994. *Population and environment: rethinking the debate.* Westview, Boulder, CO.

Bloom, D.E. 1995. International public opinion on the environment. *Science* 269: 354–358.

Boulter, M. 2002. *Extinction: evolution and the end of man.* Columbia University Press, New York, NY.

Brown, J.H. 1995. *Macroecology.* University of Chicago Press, Chicago, IL.

Catton, W.R., Jr 1980. *Overshoot: The ecological basis of revolutionary change.* University of Illinois Press, Chicago, IL.

Christensen, N.L., A.M. Bartuska, J.H. Brown, *et al.* 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. *Ecological Applications* 6: 665–691.

Coe, M. 1980. African wildlife resources. In M.E. Soulé and M.A. Wilcox (eds). *Conservation biology: an evolutionary-ecological perspective*, pp. 273–302. Sinauer Associates, Sunderland, MA.

Costanza, R. 1995. An unbalanced debate. *Bioscience* 45: 633–634.

Crosby, A.W. 1986. *Ecological imperialism: the biological expansion of Europe*, 900–1900. Cambridge University Press, New York, NY.

Curson, P. 1989. Paradise delayed: epidemics of infectious disease in the industrialized world. In J.I. Clarke, P. Curson, S.L. Kayastha, and P. Nag (eds). *Population and disaster*, pp. 157–179. Basil Blackwell, IGUCPG, Cambridge, MA.

Diamond, J.M. 1984b. Historic extinctions: a Rosetta stone for understanding prehistoric extinction. In P.S. Martin, and R.G. Klein (eds). *Quaternary extinctions: a prehistoric revolution*, pp. 824–862. University of Arizona Press, Tucson, AZ.

Diamond, J.M. 1986. The environmentalist myth. *Nature* 324: 19–20.

Diamond, J.M. 1989. Overview of recent extinctions. In D. Western, and M. Pearl (eds). *Conservation for the twenty-first century*, pp. 37–41. Oxford University Press, New York, NY.

Diamond, J.M. 2004. *Collapse: how societies choose to fail or succeed*. Viking Books, New York, NY.

Diamond, J.M. and T.J. Case. 1986. Overview: introductions, extinctions, exterminations, invasions. In J. Diamond and T.J. Case (eds). *Community ecology*, pp. 65–79 Harper and Row, New York.

Dowdle, W. 1993. The origins of plagues. *Science* 261: 1610–1611.

Ehrenfeld, D.J. 1993. *Beginning again: people and nature in the new millennium.* Oxford University Press, New York, NY.

Ehrlich, P.R. 1986. Extinction: what is happening now and what needs to be done. In D.K. Elliott (ed.). *Dynamics of extinction*, pp. 157–164. John Wiley and Sons, New York.

Ehrlich, P.R. and A.H. Ehrlich. 1981. *Extinction: the causes and consequences of the disappearance of species.* Random House, New York, NY.

Ehrlich, P.R. and A.H. Ehrlich. 1990. *The population explosion.* Simon and Schuster, New York, NY.

Ehrlich, P.R. and E.O. Wilson. 1991. Biodiversity studies: science and policy. *Science* 253: 758–762.

Ehrlich, P.R. and G.C. Daily. 1993. Science and the management of natural resources. *Ecological Applications* 3: 558–560.

Ehrlich, P.R. and J.P. Holdren. 1974. Impact of population growth. *Science* 171: 1212–1217.

Eldredge, N. 1991. *The miner's canary: unraveling the mysteries of extinction.* Prentice Hall Press, New York, NY.

Farnworth, E.G. and F.B. Golley. 1974. *Fragile ecosystems: evaluation of research and application in the neotropics.* Springer-Verlag, New York, NY.

Fowler, C.W. 2003. Tenets, principles, and criteria for management: the basis for systemic management. *Marine Fisheries Review* 65: 1–55.

Fowler, C.W. and L. Hobbs. 2002. Limits to natural variation: implications for systemic management. *Animal Biodiversity and Conservation* 25: 7–45.

Fowler, C.W., J.D. Baker, K.E.W. Shelden, P.R. Wade, D.P. DeMaster, and R.C. Hobbs. 1999. Sustainability: empirical examples and management implications. In *Ecosystem approaches for fisheries management*, pp. 305–314. University of Alaska Sea Grant, Fairbanks, Alaska, AK-SG-99-01.

Freedman, B. 1989. *Environmental ecology: the impacts of pollution and other stresses on ecosystem structure and function.* Academic Press, New York, NY.

Garrett, L. 1994. *The coming plague: newly emerging diseases in a world out of balance*. Farrar, Straus and Giroux, New York, NY.

Georghiou, G.P. 1990. Overview of insecticide resistance. In M.B. Green, H.M. LeBaron, and W.K. Moberg (eds). *Managing resistance to agrochemicals: from fundamental research to practical strategies,* pp. 18–41. American Chemical Society, Washington, DC.

Gibbons, A. 1993. Where are "new" diseases born? *Science* 261: 680–681.

Green, G.M. and R.W. Sussman. 1990. Deforestation history of the eastern rain forests of Madagascar from satellite images. *Science* 248: 212–214.

Gregg, A. 1955. A medical aspect of the population problem. *Science* 121: 681–682.

Halpern, B.S., S. Walbridge, K.A. Selkoe, *et al.* 2008. A global map of human impact on marine ecosystems. *Science* 319: 948–952.

Holt, S.J. and L.M. Talbot. 1978. New principles for the conservation of wild living resources. *Wildlife Monographs* 59: 5–33.

Karr, J.R. 1994. Protecting aquatic ecosystems: clean water is not enough. In W.S. Davis, and T.P. Simon (eds). *Biological assessment and criteria: tools for water resource planning and decision making*, pp. 7–13. Lewis Publishers, Boca Raton, FL.

Knoll, A.H. 1984. Patterns of extinction in the fossil record of vascular plants. In M.H. Nitecki (ed.). *Extinctions*, pp. 21–68 .The University of Chicago Press, Chicago, IL.

Kummer, D.M. and B.L. Turner, II. 1994. The human causes of deforestation in Southeast Asia. *Bioscience* 44: 323–328.

Law, R., J.M. McGlade, and T.K. Stokes (eds). 1993. *The exploitation of evolving resources:* Proceedings of an international conference held at Julich, Germany, Sept. 3–5, 1991. (Lecture notes in biomathematics, 99). Springer-Verlag, Berlin.

Lawton, J.H. and R.M. May (eds). 1995. *Extinction rates.* Oxford University Press, New York, NY.

Lollar, C. (ed.). 1991. Inside AAAS. *Science* 252: 586–587.

Mangel, M., L.M. Talbot, G.K. Meffe, *et al.* 1996. Principles for the conservation of wild living resources. *Ecological Applications* 6: 338–362.

Mark, A.F. and G.D. McSweeney. 1990. Patterns of impoverishment in natural communities: case history studies in forest ecosystems-New Zealand. In G.M. Woodwell (ed.). *The earth in transition; patterns and processes of biotic impoverishment*, pp. 151–176. Cambridge University Press, New York, NY.

Martin, P.S. 1986. Refuting late Pleistocene extinction models. In D.K. Elliott (ed.). *Dynamics of extinction,* pp. 107–130. John Wiley and Sons, New York.

McCormick, F.J. 1999. Principles of ecosystem management and sustainable development. In J.D. Peine (ed.). *Ecosystem management for sustainability: principles and practices illustrated by a regional biosphere reserve cooperative*, pp. 3–21. Lewis Publishers, Boca Raton, FL.

McMichael, A.J. 1993. *Planetary overload; global environmental change and the health of the human species.* Cambridge University Press, New York, NY.

MEA (Millennium Ecosystem Assessment). 2005a. *Ecosystems and human well-being: synthesis.* Island Press, Washington, DC.

MEA (Millennium Ecosystem Assessment). 2005b. *Ecosystems and human well-being: biodiversity synthesis.* World Resources Institute, Washington, DC.

Meffe, G.K. 1994. Human population control: the missing awareness. *Conservation Biology* 8: 310–313.

Meyer, W.B. and B.L. Turner (eds). 1994. *Changes in land use and land cover: a global perspective.* Cambridge University Press, New York, NY.

Morse, S.S. 1993. Examining the origins of emerging viruses. In S.S. Morse (ed.). *Emerging viruses*, pp. 10–28. Oxford University Press, New York, NY.

Morse, S.S. (ed.). 1993. *Emerging viruses.* Oxford University Press, New York, NY.

Morse, S.S. (ed.). 1993. *The evolutionary biology of viruses.* Raven, New York, NY.

Owen-Smith, R.N. 1988. *Megaherbivores: The influence of very large body size on ecology.* Cambridge University Press, New York, NY.

Perkins, J.H. 1982. *Insects, experts and the insecticide crisis: the quest for new pesticide management strategies.* Plenum Press, New York, NY.

Pimentel, D., H. Acquay, M. Biltonen, *et al.* 1992. Environmental and economic costs of pesticide use. *Bioscience* 42: 750–758.

Pimentel, D., H. Acquay, M. Biltonen, *et al.* 1993. Assessment of environmental and economic costs of pesticide use. In D. Pimentel and H. Lehman (eds). *The pesticide question: environment, economics, and ethics*, pp. 47–84. Chapman & Hall, New York, NY.

Pimm, S.L. 1991. *The balance of nature? Ecological issues in the conservation of species in communities.* The University of Chicago Press, Chicago, IL.

Pimm, S.L., G.J. Russell, J.L. Gittleman, and T.M. Brooks. 1995. The future of biodiversity. *Science* 269: 347–350.

Policansky, D. 1993. Fishing as a cause of evolution in fishes. In R. Law, J.M. McGlade, and T.K. Stokes (eds). *The exploitation of evolving resources:* Proceedings of an international conference held at Julich, Germany, Sept. 3–5, 1991, pp. 2–18. (Lecture notes in biomathematics, 99). Springer-Verlag, Berlin.

Ponting, C. 1991. *A green history of the world: the environment and the collapse of great civilizations.* Sinclair-Stevenson, London.

Postel, S. 1994. Carrying capacity: the Earth's bottom line. In L.A. Mazur (ed.). *Beyond the numbers*, pp. 48–70. Island Press, Washington, D.C.

Potts, R., and A.K. Behrensmeyer. 1992. Late Cenozoic terrestrial ecosystems. In A.K. Behrensmeyer, J.D. Damuth, W.A. DiMichele, R. Potts, H.-D. Sues, and S.L. Wing (eds). *Terrestrial ecosystems through time: evolutionary paleoecology of terrestrial plants and animals*, pp. 419–541. University of Chicago Press, Chicago, IL.

Rapport, D.J., H.A. Regier, and T.C. Hutchinson. 1985. Ecosystem behavior under stress. *American Naturalist* 125: 617–640.

Raup, D.M. 1984. Death of species. In M.H. Nitecki (ed.). *Extinctions*, pp. 1–19. The University of Chicago Press, Chicago, IL.

Raup, D.M. 1989. The case for extraterrestrial causes of extinction. *Philosophical Transactions of the Royal Society of London, Series B* 325: 421–435.

Raven, P.H. and J. Cracraft. 1999. Seeing the world as it really is: global stability and environmental change. In J. Cracraft and F.T. Grifo (eds). *The living planet in crisis: biodiversity science and policy*, pp. 287–298. Columbia University Press, New York, NY.

Redman, C.L. 1999. *Human impact on ancient environments.* University of Arizona Press, Tucson, AZ.

Simberloff, D. 1986. Are we on the verge of a mass extinction in tropical rain forests? In Elliott D.K. (ed.). *Dynamics of Extinction,* 165–180. John Wiley & Sons, New York, NY.

Singh, S.P. 1995. India's population problem, a global issue of environment and sustainability: an appeal for cooperation. *Bulletin of the Ecological Society of America* 76: 55–59.

Sisk, T.D., A.E. Launer, K.R. Switky, and P.R. Ehrlich. 1994. Identifying extinction threats. *Bioscience* 44: 592–604.

Skole, D.L., W.H. Chomentowski, W.A. Salas, and A.D. Nobre. 1994. Physical and human dimensions of deforestation in Amozonia. *Bioscience* 44: 314–322.

Smith, C.L. 1995. Assessing the limits to growth. *Bioscience* 45: 478–483.

Southwick, C.H. (ed.). 1985. *Global ecology*. Sinauer Associates, Sunderland, MA.

Specht, R.L. 1990. Changes in the eucalypt forests of Australia as a result of human disturbance. In G.M. Woodwell (ed.). *The earth in transition; patterns and processes of biotic impoverishment*, pp. 177–198. Cambridge University Press, New York, NY.

Tainter, J.A. 1988. *The collapse of complex societies*. Cambridge University Press, Cambridge.

Trotter, M.M., and B. McCulloch. 1984. Moas, men and middens. In Martin, P.S., and R.G. Klein (ed.). *Quaternary extinctions: a prehistoric revolution*, pp. 708–727. University of Arizona Press, Tucson, AZ.

Turner, B.L., II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, and W.B. Meyer (eds). 1990. *The earth as transformed by human action; global and regional changes in the biosphere over the past 300 years.* Cambridge University Press, New York, NY.

Union of Concerned Scientists. 1992. *World scientists' warning to humanity.* Available UCS Headquarters, 26 Church Street, Cambridge, MA 02238

Vitousek, P.M. 1994. Beyond global warming: ecology and global change. *Ecology* 75: 1861–1876.

Webster, R.G., and E.J. Walker. 2003. Influenza. *American Scientist* 91: 122–129.

Whitmore, T.C. 1980. The conservation of tropical rain forest. In M.E.Soulé and M.A. Wilcox (eds). *Conservation biology, an evolutionary-ecological perspective*, pp. 303–318. Sinauer Associates, Sunderland, MA.

Wilson, E.O. 1985. The biological diversity crisis. *Bioscience* 35: 700–706.

Wilson, E.O. 1985. The biological diversity crisis: a challenge to science. *Issues in Science and Technology* 2: 20–29.

Woodwell, G.M. (ed.). 1990. *The earth in transition; patterns and processes of biotic impoverishment.* Cambridge University Press, New York, NY.

World Conservation Monitoring Centre. 1992. *Global biodiversity.* Chapman & Hall, New York, NY.

Yoffee, N. and G.L. Cowgill (eds). 1988. *The collapse of ancient states and civilizations.* University of Arizona Press, Tucson, AZ.