13 CONCLUSION

The power of nonindustrial and pre-industrial civilizations

It has become apparent that Marsh was correct over a century ago to express his cogently argued views of the importance of human agency in environmental change. Since his time the impact that humans have had on the environment has increased, as has our awareness of this impact. There has been 'a screeching acceleration of so many processes that bring ecological change' (McNeill, 2000: 4). However, it is worth making the point here that, although much of the concern expressed about the undesirable effects humans have tends to focus on the role played by sophisticated industrial societies, this should not blind us to the fact that many highly significant environmental changes were and are being achieved by nonindustrial societies.

In recent years it has become apparent that fire, in particular, enabled early societies to alter vegetation substantially, so that plant assemblages that were once thought to be natural climatic climaxes may in reality be in part anthropogenic fire climaxes. This applies to many areas of both savanna and mid-latitude grassland (see p. 39). Such alteration of natural vegetation has been shown to re-date the arrival of European settlers in the Americas (Denevan, 1992), New Zealand, and elsewhere. The effects of fire may have been compounded by the use of the stone axe and by the grazing effects of domestic animals. In turn the removal and modification of vegetation would have led to adjustment in fauna. It is also apparent that soil erosion resulting from vegetation removal has a long history and that it was regarded as a threat by the classical authors.

Recent studies (see p. 50) tend to suggest that some of the major environmental changes in highland Britain and similar parts of western Europe that were once explained by climatic changes can be explained more effectively by the activities of Mesolithic and Neolithic peoples. This applies, for example, to the decline in the numbers of certain plants in the pollen record and to the development of peat bogs and podzolization (see p. 103). Even soil salinization started at an early date because of the adoption of irrigation practices in arid areas, and its effects on crop yields were noted in Iraq more than 4000 years ago (see p. 102). Similarly (see p. 84) there is an increasing body of evidence that the hunting practices of early civilization may have caused great changes in the world's megafauna as early as 11,000 years ago.

In spite of the increasing pace of world industrialization and urbanization, it is plowing and pastoralism which are responsible for many of our most serious environmental problems and which are still causing some of our most widespread changes in the landscape. Thus, soil erosion brought about by agriculture is, it can be argued, a more serious pollutant of the world's waters than is industry: many of the habitat changes which so affect wild animals are brought about through agricultural expansion (see p. 79); and soil salinization and desertification can be regarded as two of the most serious problems facing the human race. Land-use changes, such as the conversion of forests to fields, may be as effective in causing anthropogenic changes in climate as the more celebrated burning of fossil fuels and emission of industrial aerosols into the atmosphere. The liberation of CO_2 in the atmosphere through agricultural expansion, changes in surface albedo values, and the production of dust, are all major ways in which agriculture may modify world climates. Perhaps most remarkably of all, humans, who only represent roughly 0.5% of the total heterotroph biomass on Earth, appropriate for their use something around one-third of the total amount of net primary production on land (Imhoff et al., 2004).

The proliferation of impacts

A further point we can make is that, with developments in technology, the number of ways in which humans are affecting the environment is proliferating. It is these recent changes, because of the uncertainty which surrounds them and the limited amount of experience we have of their potential effects, which have caused greatest concern. Thus it is only since the Second World War, for example, that humans have had nuclear reactors for electricity generation, that they have used powerful pesticides such as DDT (dichlorodiphenyltrichloroethane), and that they have sent supersonic aircraft into the stratosphere. Likewise, it is only since around the turn of the century that the world's oil resources have been extensively exploited, that chemical fertilizers have become widely used, and that the internal combustion engine has revolutionized the scale and speed of transport and communications.

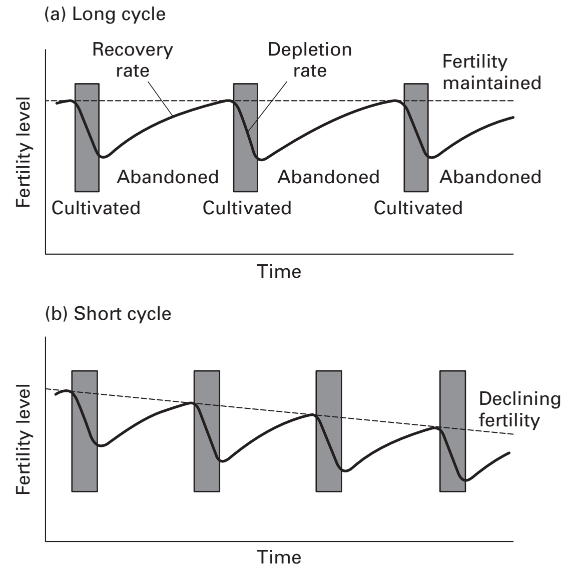

Figure 13.1 Land rotation and population density. The relationship of soil fertility cycles to cycles of slash-and-burn agriculture: (a) fertility levels are maintained under the long cycles characteristic of low-density populations; (b) fertility levels are declining under the shorter cycles characteristic of increasing population density. Notice that in both diagrams the curves of both depletion and recovery have the same slope (after Haggett, 1979, figure 8.4).

Above all, however, the complexity, frequency, and magnitude of impacts are increasing, partly because of steeply rising population levels and partly because of a general increase in *per capita* consumption. Thus some traditional methods of land use, such as shifting agriculture (see p. 36) and nomadism, which have been thought to sustain some sort of environmental equilibrium, seem to break down and to cause environmental deterioration when population pressures exceed a particular threshold. This is illustrated for shifting agriculture systems by Figure 13.1, which shows the relationship of soil fertility levels to cycles of slash-and-burn agriculture. Fertility can be maintained (Figure 13.1a) under the long cycles characteristic of low-density populations. However, as population levels increase, the cycles necessarily become shorter, and soil fertility levels are not maintained, thereby imposing greater stresses on the land (Figure 13.1b).

Figure 13.2 The impact of recreation pressures is well displayed at a prehistoric hill-fort, Badbury Rings, Dorset, England. Pedestrians and motorcyclists have caused severe erosion of the ramparts.

At the other end of the spectrum, increasing incomes, leisure, and ease of communication have generated a stronger demand for recreation and tourism in the developed nations (Figure 13.2). These have created additional environmental problems (see p. 62), especially in coastal and mountain areas. Some of the environmental consequences of recreation, which are reviewed at length by Liddle (1997), can be listed as follows:

1 desecration of cave formations by speleologists;
2 trampling by human feet leading to soil compaction;
3 nutrient additions at campsites by people and their pets;
4 decrease in soil temperatures because of snow compaction by snowmobiles;
5 footpath erosion and off-road vehicle erosion;
6 dune reactivation by trampling;
7 vegetation change due to trampling and collecting;
8 creating of new habitats by cutting trails and clearing campsites;
9 pollution of lakes and inland waterways by gasoline discharge from outboard motors and by human waste;
10 creation of game reserves and protection of ancient domestic breeds;
11 disturbance of wildlife by proximity of persons and by hunting, fishing, and shooting;
12 conservation of woodland for pheasant shooting.

Likewise, it is apparent when considering the range of possible impacts of one major type of industrial development that they are significant. As Table 13.1 indicates, the exploitation of an oilfield and all the activities that it involves (e.g., pipelines, new roads, refineries, drilling, etc.) have a wide range of likely effects on land, air, water, and organisms.

Conversely, if one takes one ecosystem type as an example – the coral reef – one can see the diversity of stresses to which it is now being exposed (Figure 13.3) as a result of a whole range of different human activities, which include global warming, increased sedimentation and pollution from river runoff, and overharvesting of fish and other organisms (Bellwood et al., 2004).

A very substantial amount of change has been achieved in recent decades. Table 13.2, based on the work of Kates et al. (1990), attempts to make quantitative comparisons of the human impact on ten 'component indicators of the biosphere'. For each component they defined total net change clearly induced by humans to be 0% for 10,000 years ago and 100% for 1985. They estimated dates by which each component had reached successive quartiles (i.e., 5, 50 and 75%) of its 1985 total change. They believe that about half of the components have changed more in the single generation since 1950 than in the whole of human history before that date.

Are changes reversible?

It is evident that while humans have imposed many undesirable and often unexpected changes on the environment, they often have the capacity to modify the rate of such changes or to reverse them. There are cases where this is not possible: once soil has been eroded from an area it cannot be restored; once a plant or animal has become extinct it cannot be brought back; and once a laterite iron pan has become established it is difficult to destroy.

However, through the work of George Perkins Marsh and others, people became aware that many of the changes that had been set in train needed to be reversed or reduced in degree. Sometimes this has simply involved discontinuing a practice which has proved undesirable (such as the cavalier use of DDT or CFCs), or replacing it with another which is less detrimental

Table 13.1 Qualitative environmental impacts of mineral industries with particular reference to an oilfield. Source: Denisova (1977: 650, table 2)

Facility	*Direction of the impact and reaction to the environment*			
	Land	*Air*	*Water*	*Biocenosis*
Well	Alienation of land surface Extraction of oil associated gas, groundwater Pollution by crude oil, refined products, drilling mud Disturbance of internal structure of soil and subsoil Destruction of soil	Pollution by associated gas and volatile hydrocarbons, products of combustion	Withdrawal of surface water and groundwater Pollution by crude oil and refined products, salination of freshwater Disturbance of water balance of both subsurface and surface waters	Pollution by crude oil and refined products Disturbance and destruction over a limited surface area
Pipeline	Alienation of land Accidental oil spills Disturbance of landforms and internal structure of soil and subsoil	Pollution by volatile hydrocarbons	Disturbance and destruction over limited surface area	
Motor roads	Alienation of land Pollution by oil products Disturbance of landforms and internal structure of soil and subsoil	Pollution by combustion products, volatile hydrocarbons, sulfur dioxide, nitrogen oxides	Pollution by combustion products Disturbances and destruction over limited surface area	
Collection point	Alienation of land Pollution by crude oil and refined products (spills) Disturbance of internal structure of soil and subsoil	Pollution by volatile hydrocarbons	Disturbance and destruction over limited surface area	

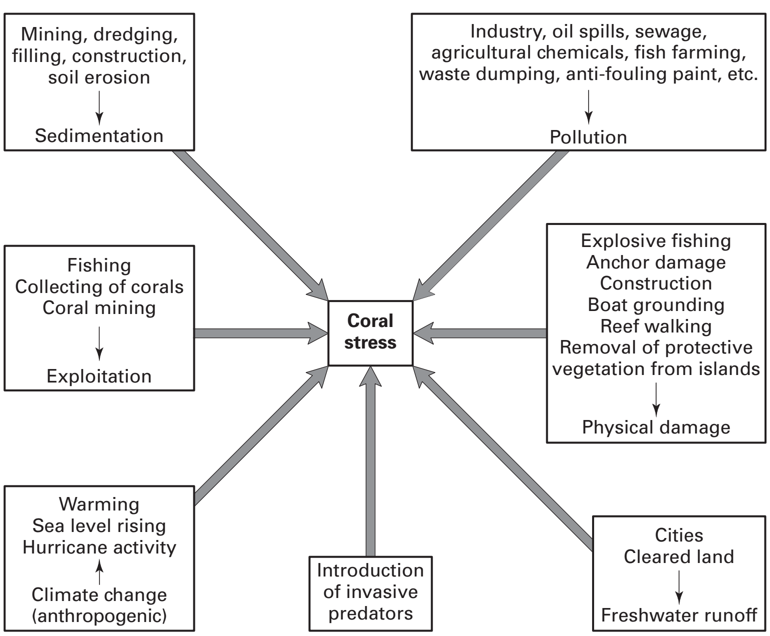

Figure 13.3 Some causes of anthropogenic stress on coral reef ecosystems.

Table 13.2 Chronologies of human-induced transformations. Source: from Kates et al. (1990, table 1.3).
(a) Quartiles of change from 10,000 BC to mid-1980s

Form of transformation	*Dates of quartiles*		
	25%	*50%*	*75%*
Deforested area	1700	1850	1915
Terrestrial vertebrate diversity	1790	1880	1910
Water withdrawals	1925	1955	1975
Population size	1850	1950	1970
Carbon releases	1815	1920	1960
Sulfur releases	1940	1960	1970
Phosphorus releases	1955	1975	1980
Nitrogen releases	1970	1975	1980
Lead releases	1920	1950	1965
Carbon tetrachloride production	1950	1960	1970

(b) Percentage change by time of Marsh and Princeton symposium

Form of transformation	*Percentage change*	
	1860	*1950*
Deforested area	50	90
Terrestrial vertebrate diversity	25–50	75–100
Water withdrawals	15	40
Population size	30	50
Carbon releases	30	65
Sulfur releases	5	40
Phosphorus releases	< 1	20
Nitrogen releases	< 1	5
Lead releases	5	50
Carbon tetrachloride production	0	25

in its effects. Often, however, specific measures have been taken which have involved deliberate decisions of management and conservation. Denson (1970), for example, outlines a sophisticated six-stage model for wildlife conservation:

1 immediate physical protection from humans and from changes in the environment;
2 educational efforts to awaken the public to the need for protection and to gain acceptance of protective measures;
3 life-history studies of the species to determine their habitat requirements and the causes of their population decline;
4 dispersion of the stock to prevent loss of the species by disease or by a chance event such as fire;
5 captive breeding of the species to assure higher survival of young, to aid research, and to reduce the chances of catastrophic loss;
6 habitat restoration or rehabilitation when this is necessary before introducing the species.

Many conservation measures have been successful, while others have created as many problems as they were intended to solve. This applies, for example, to certain schemes for the reduction of coast erosion. On balance, however, there has been notable progress in dealing with such problems as acid rain in Europe, and the depletion of stratospheric ozone. Many governments, though not all, have signed up to the Kyoto Protocol in an attempt to reduce greenhouse gas emissions.

The concern with preservation and conservation has been longstanding, with many important landmarks. Interest has grown dramatically in recent years. Lowe (1983) has identified four stages in the history of British nature conservation:

1 the natural history/humanitarian period (1830–90)
2 the preservation period (1870–1940)
3 the scientific period (1910–70)
4 the popular/political period (1960–present)

The first of these stages was rooted in a strong enthusiasm for natural history, and the crusade against cruelty to animals. Although many Victorian naturalists were avid collectors, numerous clubs were established to study nature and some of them sought to preserve species to make them available for observation. As we shall see, certain acts were introduced at this time to protect birds. During the preservationist period, there was the formation of a spate of societies devoted to preserving open land and its associated wildlife (e.g., the National Trust, 1894; and the Council for the Preservation of Rural England, 1926). There was a growing sense of vulnerability of wildlife and landscapes to urban and industrial expansion and geographers such as Vaughan Cornish (see Goudie, 1972b) campaigned for the creation of national parks and the preservation of scenery, made possible through the National Parks and Access to Countryside Act of

1949. From the First World War onwards ecological research developed, and there arose an increasing understanding of ecological relationships. Scientists pressed for the regulation of habitats and species, and the Nature Conservancy Council was established in 1949. In the 1960s and the years that followed popular interest in conservation and widespread media attention first developed. This was partly generated by pollution incidents (such as the wrecks of the *Torrey Canyon* and *Amoco Cadiz*), and a gathering sense of impending environmental doom, generated by such persuasive books as Rachel Carson's *Silent Spring*. Ecology became a political issue in various European nations, including the UK. In many countries major developments in land use, construction, and industrialization now have to be preceded by the production of an Environmental Impact Assessment, and the European Union has introduced measures such as the Water Framework Directive (2000) and the Landfill Directive to improve the ecological status of water resources.

Thus in some countries, and in connection with particular species, conservation and protection have had a long and sometimes successful impact. In Britain, for example, the Wild Birds Protection Act dates back to 1880, and the Sea Birds Protection Act even further to 1869. The various acts have been modified and augmented over the years to outlaw egg-collecting, pole-trapping, plumage importation, and the capture or possession of a range of species. The effectiveness of the different acts can be measured in real terms. Over the past 60 years no species have been lost as British breeding birds due to lack of protection – the only major loss has been the Kentish plover, which was in any case on the edge of its range. Perhaps more importantly, several species have successfully recolonized Britain, the most celebrated being the avocet and the osprey. Today both are firmly established, together with other species lost in the nineteenth century: the black-tailed godwit, the goshawk, and the bittern. Also as a result of protection the red kites of Wales have not only survived but also increased in number, and the peregrine falcon maintains its largest numbers in Europe outside Spain.

One further ground which gives some basis for hope that humans soon may be reconciled with the environment is that there are some signs of a widespread shift in public attitudes to nature and the environment. These changing social values, combined with scientific facts, influence political action. This point of view, which acts as an antidote for some of the more pessimistic views of the world's future, was elegantly presented by Ashby (1978). He contended that the rudiments of a healthy environmental ethic are developing, and explained (pp. 84–5)

> Its premise is that respect for nature is more moral than lack of respect for nature. Its logic is to put the Teesdale Sandwort . . . into the same category of value as a piece of Ming porcelain, the Yosemite Valley in the same category as Chartres Cathedral: a Suffolk landscape in the same category as a painting of the landscape by Constable. Its justification for preserving these and similar things is that they are unique, or irreplaceable, or simply part of the fabric of nature, just as Chartres and the painting by Constable are part of the fabric of civilisation; also that we do not understand how they have acquired their durability and what all the consequences would be if we destroy them.

Although there may be considerable controversy surrounding the precise criteria that can be used to select and manage sites that are particularly worthy of conservation (Goldsmith, 1983), there are nonetheless many motives behind the increasing desire to protect species and landscapes. These can be listed under the following general headings:

1 *The ethical.* It is asserted that wild species have a right to coexist with us on our planet, and that we have no right to exterminate them. Nature, it is maintained, is not simply there for humans to transform and modify as they please for their own utilitarian ends.
2 *The scientific*. We know very little about our surrounding environments, including, for example, the rich insect faunas of the tropical rain forest; therefore such environments should be preserved for future scientific study.
3 *The aesthetic.* Plants and animals, together with landscapes, may be beautiful and so enrich the life of humans.
4 *The need to maintain genetic diversity*. By protecting species we maintain the species diversity upon which future plant- and animal-breeding work will depend. Once genes have been lost (see Chapter 2, section on 'The change in genetic and species diversity') they cannot be replaced.

5 *Environmental stability*. It is argued that in general the more diverse an ecosystem is, the more checks and balances there are to maintain stability. Thus environments that have been greatly simplified by humans may be inherently unstable, and prone to disease, etc.
6 *Recreational.* Preserved habitats and landscapes have enormous recreational value, and in the case of some game reserves and natural parks may have economic value as well (e.g., the safari industry of East Africa).
7 *Economic*. Many of the species in the world are still little known, and there is the possibility that we have great storehouses of plants and animals, which, when knowledge improves, may become useful economic resources.
8 *Future generations.* One of the prime arguments for conservation, whether of beautiful countryside, rare species, soil, or mineral resources, is that future generations (and possibly ourselves later in life) will require them, and may think badly of a generation that has squandered them.
9 *Unintended impacts.* As we have seen so often in this book, profligate or unwise actions can lead to side-effects and consequences that may be disadvantageous to humans.
10 *Spiritual imperatives.* This includes a belief in the need for environmental stewardship.

Some of these arguments are more utilitarian than others (e.g., 4, 5, 6, 7 and 9), and some may be subject to doubt – it could, for example, be argued that future generations will have technology to use new resources and may not need some of those we regard as essential – but overall they provide a broadly based platform for the conservation ideal (Myers, 1979).

The susceptibility to change

Ecosystems respond in different ways to the human impact, and some are more vulnerable to human perturbation than others (Kasperson et al., 1995). It has often been thought, for example, that complex ecosystems are more stable than simple ones. Thus in Clements' Theory of Succession the tendency towards community stabilization was ascribed in part to an increasing level of integration of community functions. As Goodman (1975: 238) has expressed it:

> In general the predisposition to expect greater stability of complex systems was probably a combined legacy of eighteenth century theories of political economics, aesthetically and perhaps religiously motivated attraction to the belief that the wondrous variety of nature must have some purpose in an orderly work, and ageless folkwisdom regarding eggs and baskets.

Indeed, as Murdoch (1975) has pointed out, it makes good intuitive sense that a system with many links, or 'multiple fail-safes', is more stable than one with few links or feedback loops. As an example, if a type of herbivore is attacked by several predatory species, the loss of any one of these species will be less likely to allow the herbivore to erupt or explode in numbers than if only one predator species were present and that single predator type disappeared. The basic idea therefore is that diverse groups of species are more stable because complementary species compensate for one another if one species suffers severe declines (Doak and Marvier, 2003). A diverse ecosystem will have a variety of species that help to insure it against a range of environmental upsets (Naeem, 2002).

Various other arguments have been marshaled to support the idea that great diversity and complexity affords greater ability to minimize the magnitude, duration, and irreversibility of changes brought about by some external perturbation such as human activity (Noy-Meir, 1974). It has been stated that natural systems, which are generally more diverse than artificial systems such as crops or laboratory populations, are also more stable. Likewise, the tropical rain forest has been thought of as more diverse and more stable than less complex temperate communities, while simple Arctic ecosystems of oceanic islands have always appeared highly vulnerable to disturbance brought about by anthropogenic plant and animal introductions (see p. 54).

However, considerable doubt has been expressed as to whether the classic concept of the causal linkage between diversity/complexity and stability is entirely valid (see, e.g., Hurd et al., 1971). Murdoch (1975) indicated that there is not convincing field evidence that diverse natural communities are generally more stable than simple ones. He cited various papers which show that fluctuations of microtine rodents (lemmings, field voles, etc.) are as violent in relatively complex temperate zone ecosystems as they are in the less complex Arctic zone ecosystems. This was supported by Goodman (1975: 239) who wrote:

> As for the apparent stability of tropical biota, that could well be an illusion attributable to insufficient study of bewilderingly complex assemblages in which many species are so poorly represented in samples of feasible size that even considerable fluctuations might go undetected. Indeed, there are countervailing anecdotes regarding ecological instability in the tropics, such as recent reports on an insect virtually defoliating the wild Brazil-nut trees in Bolivia and of monkeys succumbing in large numbers to epidemics.

He went on to add: 'There is growing awareness of the surprising susceptibility of the rain forest ecosystems to man-made perturbation.' This is a point of view supported by May (1979) and discussed by Hill (1975). Hill pointed out that a very high species diversity is frequently associated with areas which have relatively constant physical environmental conditions over the course of a year and a series of years. The rain forest may be construed to be such an environment, and one where this constancy has allowed the presence of many specialized species, each pursuing a narrow range of activities. It has been argued that because of the high degree of specialization, the indigenous species have a limited ability to recover from major stresses caused by human intervention.

Goodman (1975) has also queried the sufficiency of the argument in its reference to the apparent instability of island ecosystems, suggesting that islands, being evolutionary backwaters and dead-ends, may accumulate species that are especially susceptible to competitive or exploitative displacement. In this case, lack of diversity may not necessarily be the sole or prime cause of instability.

The apparent instability of agricultural compared with natural communities is also often attributed to lack of diversity (see p. 62), and indeed modern agriculture does involve significant ecosystem simplification. However, such instability as there is may not, once again, necessarily result from simplification. Other factors could promote instability: agricultural communities are disrupted, even destroyed, more frequently and more massively as part of the cultivation process than those natural systems we tend to think of as stable; the component species of natural systems are co-evolved (co-adapted), and this is not usually true of agricultural communities. As Murdoch (1975: 799) suggests, it may be that:

> Natural systems are more stable than crop systems because their interacting species have had a long shared evolutionary history. In contrast with these natural communities the dominant plant species of a crop system is thrust into an often alien landscape . . . the crops have undergone radical selection in breeding programs, often losing their genetic defense mechanisms.

Thus the idea that complex natural ecosystems will be less susceptible to human interference and that simple artificial ecosystems will inevitably be unstable are not necessarily tenable. Nonetheless, it is apparent that there are differences in susceptibility between different ecosystem types, and these differences may result from factors other than the degree of diversity and complexity (Cairns and Dickson, 1977).

Some systems tend to be *vulnerable*. Lakes, for example, are natural traps and sinks and are thus more vulnerable to the effect of disadvantageous inputs than are rivers (which are continually receiving new inputs) or oceans (which are so much larger). Other systems display the property of *elasticity* – the ability to recover from damage. This may be because nearby epicenters exist to provide organisms to reinvade a damaged system. Small, isolated systems will often tend to possess low elasticity (see p. 88). Two of the most important properties, however, are *resilience* (being a measure of the number of times a system can recover after stress), and *inertia* (the ability to resist displacement of structural and functional characteristics).

Two systems which display resilience and inertia are deserts and estuaries. In both cases their indigenous organisms are highly accustomed to variable environmental conditions. Thus most desert fauna and flora evolved in an environment where the normal pattern is one of more or less random alternations of short favorable periods and long stress periods. They have pre-adapted resilience (Noy-Meir, 1974) so that they can tolerate extreme conditions, have the ability for rapid recovery, have various delay and trigger mechanisms (in the case of plants), and have flexible and opportunistic eating habits (in the case beasts). Estuaries, on the other hand, although the subject of increasing human pressures, also display some resilience. The vigor of their water circulation continuously and endogenously renews the supply of water, food, larvae, etc.; this aids recovery. Also, many species have biological characteristics that provide special advantages in estuarine survival. These characteristics usually protect the species against the natural violence of estuaries and are often helpful in resisting external forces such as humans.

The relationship between biodiversity and ecosystem stability continues to be a hot topic in ecology (Loreau et al., 2002; Kareiva and Levin, 2003). Some studies continue to throw doubt upon any simple relationship between biodiversity and stability (e.g., Pfisterer and Schmid, 2002), but there is perhaps an emerging consensus that diversity is crucial to ecosystem operation (McCann, 2000). As Loreau et al. (2001: 807) write,

> There is consensus that at least some minimum number of species is essential for ecosystem functioning under constant conditions and that a larger number of species is probably essential for maintaining the stability of ecosystem processes in changing environments.

Human influence or nature?

From many of the examples given in this book it is apparent that in many cases of environmental change it is impossible to state, without risk of contradiction, that people rather than nature are responsible. Most systems are complex and human agency is but one component of them, so that many human actions can lead to end-products that are intrinsically similar to those that may be produced by natural forces. How to distinguish between human-induced perturbations and ill-defined natural oscillations is a crucial question when considering issues such as coral reef degradation (Sapp, 1999). It is a case of equifinality, whereby different processes can lead to basically similar results. Humans are not always responsible for some of the changes with which they are credited. This book has given many examples of this problem and a selection is presented in Table 13.3. Deciphering the cause is often a ticklish problem, given the intricate interdependence of different components of ecosystems, the frequency and complexity of environmental changes, and the varying relaxation times that different ecosystem components may have when subject to a new impulse. This problem plainly does not apply to the

Table 13.3 Human influence or nature? Some examples, with page references to this book where applicable

Change	*Causes*		
	Natural	*Anthropogenic*	*Page reference*
Late Pleistocene animal extinction	Climate	Hunting	84
Death of savanna trees	Soil salinization through climatically induced groundwater rise	Overgrazing	–
Desertification of semi-arid areas	Climatic change	Overgrazing, etc.	42
Holocene peat-bog development in highland Britain	Climatic change and progressive soil deterioration	Deforestation and plowing	103
Holocene elm and linden decline	Climatic change	Feeding and stalling of animals	51
Tree encroachment into alpine pastures in USA	Temperature amelioration	Cessation of burning	–
Gully development	Climatic change	Land-use change	171
Late twentieth-century climatic warming	Changes in solar emission and volcanic activity	CO_2-generated greenhouse effect	196
Increasing coast recession	Rising sea level	Disruption of sediment supply	185
Increasing coastal flood risk	Rising sea level, natural subsidence	Pumping of aquifers creating subsidence	168
Increasing river flood intensity	Higher intensity rainfall	Creation of drainage ditches	134
Ground collapse	Karstic process	Dewatering by overpumping	157
Forest decline	Drought	Air, soil, and water pollution	59

same extent to changes that have been brought about deliberately and knowingly by humans, but it does apply to the many cases where humans may have initiated change inadvertently and unintentionally.

This fundamental difficulty means that environmental impact statements of any kind are extremely difficult to make. As we have seen, humans have been living on the earth and modifying it in different degrees for several millions of years, so that it is problematic to reconstruct any picture of the environment before human intervention. We seldom have any clear baseline against which to measure changes brought about by human society. Moreover, even without human interference, the environment would be in a perpetual state of flux on a great many different timescales. In addition, there are spatial and temporal discontinuities between cause and effect. For example, erosion in one locality may lead to deposition in another, while destruction of key elements of an animal's habitat may lead to population declines throughout its range. Likewise, in a time context, a considerable interval may elapse before the full implications of an activity are apparent. Also, because of the complex interaction between different components of different environmental systems and subsystems, it is almost impossible to measure total environmental impact. For example, changes in soil may lead to changes in vegetation, which in turn may trigger changes in water quality and in animal populations. Primary impacts give rise to a myriad of successive repercussions throughout ecosystems, which may be impracticable to trace and monitor. Quantitative cause-and-effect relationships can seldom be established.

Into the unknown

During the 1980s and 1990s the full significance of possible future environmental changes has become apparent, and national governments and international institutions have begun to ponder whether the world is entering a spasm of unparalleled humanly induced modification. For example, Steffen et al. (2004) have suggested that Earth is currently operating in a no-analogue state. They remark (p. 262):

> In terms of key environmental parameters, the Earth System has recently moved well outside the range of the natural variability exhibited over at least the last half million years. The nature of changes now occurring simultaneously in the Earth System, their magnitudes and rates of change are unprecedented.

Likewise, the Amsterdam Declaration of 2001 pointed to the role of thresholds and surprises (see Steffen et al., 2004, p. 298):

> Global change cannot be understood in terms of a simple cause-effect paradigm. Human-driven changes cause multiple effects that cascade through the Earth System in complex ways. These effects interact with each other and with local- and regional-scale changes in multidimensional patterns that are difficult to understand and even more difficult to predict. Surprises abound.
>
> Earth System dynamics are characterized by critical thresholds and abrupt changes. Human activities could inadvertently trigger such changes with severe consequences for Earth's environment and inhabitants.

Our models and predictions are still highly inadequate, and there are great ranges in some of the values we give for such crucial changes as sea-level rise and global climatic warming, but the balance of scientific argument favors the view that change will occur and that change will be substantial. Some of the changes may be advantageous for humans or for particular ecosystems; others will be extremely disadvantageous.

It is clear that many environmental problems are interrelated and transboundary in scope so that integrated approaches and international cooperation are required. Environmental issues and environmental solutions have become globalized (Steffen et al., 2004, p. 290).

Some environments will change very substantially during the twenty-first century in response to a rise of land-use changes and climatic changes, with some predictions suggesting that the world's grasslands and Mediterranean biomes being particularly impacted (Sala et al., 2000). Marine ecosystems will also be impacted and Jenkins (2003: 1176) suggests that by 2050: 'If present trends . . . continue, the world's marine ecosystems in 2050 will look very different from today's, large species, and particularly top predators, will be by and large extremely scarce and some will have disappeared entirely . . .' Human populations will increase, and will probably be greater by 2 to 4 billion people by 2050 (Cohen, 2003).

But all change, if it is rapid and of a great magnitude, is likely to create uncertainties and instabilities. The study of future events will not only become a major concern for the environmental sciences but will also become a major concern for economists, sociologists, lawyers, and political scientists. George Perkins Marsh was a lawyer and politician, but it is only now, over a century since he wrote *Man and nature*, that the wisdom, perspicacity, and prescience of his ideas have begun to be given the praise and attention they deserve.

Points for review

Why has there been a 'screeching acceleration' in the twentieth century of so many processes that bring ecological change?

How may adverse environmental changes be reversed?

Why should one conserve nature?

In the context of ecosystems, what do you understand by such terms as 'stability', 'resilience', 'elasticity', and 'inertia'?

Why is it often difficult to disentangle natural and anthropogenic causes of environmental changes?

Guide to reading

Liddle, M., 1997, *Recreation ecology*. London: Chapman and Hall. An excellent review of the multiple ways in which recreation and tourism have an impact on the environment.

O'Riordan, T. (ed.), 1995, *Environmental science for environmental management*. Harlow: Longman Scientific. A multi-author guide to managing environmental change.

Roberts, N. (ed.), 1994, *The changing global environment*. Oxford: Blackwell. A good collection of case studies with a wide perspective.

Simon, J. L. (ed.), 1995, *The state of humanity*. Oxford: Blackwell. A multi-author work with an optimistic message.

Simon, J. L., 1996, *The ultimate resource 2*. Princeton: Princeton University Press. A view that the state of the world is improving.

Steffen, W. and 10 others, 2004, *Global change and the earth system*. Berlin: Springer. Chapter 6 of this multi-author volume addresses ways of global management for global sustainability.

Turner, B. L. (ed.), 1990, *The Earth as transformed by human action*. Cambridge: Cambridge University Press. A magnificent study of change in the past 300 years.