CAMBRIDGE

Cambridge University Press
978-0-521-67982-4 - Environmental Biology
Edited by Mike Calver, Alan Lymbery, Jen McComb and Mike Bamford
Excerpt
More information

Theme 1

What is environmental biology?

About 65 million years ago, life on Earth was stressed by global climate change and rising sea levels. At this time, two large asteroids struck the planet simultaneously in North and South America. The impacts threw a huge dust cloud into the atmosphere and blocked the sun for at least several months. They also coincided with the extinction of the large dinosaurs and profound changes in other life.

Biologist Peter Ward has called attention to similarities between that time and our own. Climate change and rising sea levels are stressing the world's biota again and, to use Ward's analogy, another 'asteroid' struck in Africa about 100 000 years ago – the evolution of the human species. Ward argues that the rise of humans has meant the diminishment of the great diversity of life on Earth, in just the same way as the impacts of the earlier asteroids altered the direction of evolution.

In this first theme of *Environmental Biology* we examine why an understanding of our species is essential to understanding and conserving the diversity of life.

1

Environmental biology and our time

Mike Calver, Alan Lymbery and Jen McComb

Setting the scene

About 40 years ago, the first comprehensive biology textbook written specifically for Australian students opened with the photograph in Figure 1.1, showing a flock of sheep in a paddock.

Figure 1.1 An Australian sheep paddock. (Source: Morgan, D. (supervising editor) (1973). *Biological science: the web of life.* Australian Academy of Science, Canberra)

The scene was typical of many agricultural areas in Australia then, and remains so today. The authors commented on the questions a biologist might ask when viewing the picture: why do the sheep prefer to stand in the shade? Why are there no sheep under the far tree? Why are there no young trees in the paddocks? Today, those questions seem less relevant. A contemporary biologist might ask: what was the landscape like before the establishment of European agriculture? What plants and animals have been lost from this area? Are there signs of land degradation and, if so, how could they be reversed? Is the agricultural production sustainable? If not, what are the implications for local human communities? These new questions reveal a growing concern about the impacts of expanding human populations and the application of new technologies on the natural environment.

Chapter aims

This chapter describes how the success of the world's dominant animal species, humans, has severely altered biodiversity and natural ecosystems. Three in-depth examples of environmental problems are introduced, together with an explanation of the knowledge and skills biologists need to reverse or mitigate such problems.

Humans and environmental problems

The environment can be regarded as a series of linked ecosystems, each of which includes all the organisms of a given area and the physical surroundings with which they interact. Collectively, the ecosystems of the Earth form the biosphere. They provide an enormous range of 'goods and services' for human populations, including food production, cycling of nutrients important for agricultural productivity, water purification, oxygen production, preservation of topsoil, and a wide range of renewable materials such as drugs, fibres and timber. Humans are now placing great demands on these services as a result of our population growth and increasing resource consumption.

The human population density a million years ago has been estimated at about $0.004/km^2$. By 10 000 years ago it had increased to $0.04/km^2$, by 2000 years ago it had reached $1.0/km^2$ and by the early 19th century it was $6.2/km^2$, rising further to $46.0/km^2$ by the turn of the 21st century. Current projections suggest a global population of about 11 billion, or over $90.0/km^2$, by 2050. Over the same period, technology has advanced from simple tools of stone, bone and wood powered by human muscle, to modern sophisticated metalworking, electronics and machines powered by fossil fuels. Thus the capacity for rapid modification of the environment has grown along with the population. For example, at present humans divert about 50% of accessible fresh water on the Earth for our own use. Every extinction of an organism on the Earth in the last 200 years has probably involved human activity. About 7% of the productive capacity of the Earth's terrestrial ecosystems is lost annually as a result of human-caused habitat degradation. We could mention many other examples.

Why should we care? Much concern about the environment stems from two utilitarian reasons: the usefulness of many products that the environment provides and the essential need to maintain the ecosystem services upon which human life depends. Aside from these, people are concerned about the aesthetic value of natural environments and the organisms within them, and argue that their preservation enriches human life. The yearning for wildlife and wild places is now reflected in a burgeoning environmental tourism industry, which seeks to provide people with such experiences. A further issue is one of ethics. If any one human generation destroys a non-renewable environmental asset, then that asset is unavailable to future generations and their quality of life might be reduced as a result. Each generation has a custodial responsibility for the quality of the environment.

Overall, the human species is the critical factor in understanding environmental biology. It is both the problem, because of its impacts, and the solution, because the impacts are preventable. Therefore this chapter begins with a discussion of the human species, exploring the reasons for its success and for its effects on the Earth's ecosystems. Then three case studies of environmental problems are introduced:

1. the conflict between timber production and conservation of Leadbeater's possum (*Gymnobelideus leadbeateri*) in the mountain highlands of Victoria, Australia
2. concern as to whether damaging outbreaks of crown-of-thorns starfish (*Acanthaster planci*) on tropical reefs have a human cause, and
3. conservation of a rare plant species, the Corrigin grevillea (*Grevillea scapigera*), following extensive land clearing for agriculture in the wheat belt of Western Australia.

Each case study highlights the background knowledge necessary to solve environmental problems, and thus the relevance of the background studies presented in this book. In later chapters we will revisit these problems to demonstrate progress in developing solutions.

The human animal

Evolutionary origins of modern humans

Many of the steps in the evolution of humans are open to different interpretations because the incomplete nature of the fossil record makes it difficult to build a conclusive case. However, it appears that the human lineage separated from that of the great apes about 5–7 million years ago. The stimulus may have been climate change turning the tropical forests of southern and eastern Africa into open woodland with large gaps in the canopy and, still later, into wooded savanna. Walking upright on the hind limbs – bipedalism – aided the mobility of ancestral humans in the changed environment, increased their range of vision and also freed their forelimbs for manipulating objects. This in turn may have encouraged brain development and opened new opportunities for finding and using environmental resources by means of tools, which are external objects that extend the body's functions to achieve an immediate goal. Steady increases in brain size and, with them, increasing skill in tool making and environmental modification have characterised human evolution ever since.

Overall, the major evolutionary trends in the development of humans involved:

1. bipedal posture (walking on two legs)
2. a considerable increase in brain size, both in absolute volume and also in proportion to overall body size (a modern human has a brain volume of about 1450 mL, compared with 400 mL in a chimpanzee)
3. a shortening of the jaws and flattening of the face (perhaps the increasing use of tools to prepare food and for defence reduced the need for large jaws and teeth)
4. reduced sexual dimorphism, with males being only slightly larger than females and
5. a long period of infant dependence on the parents, which in turn may have promoted both long-term pair-bonding and increased opportunities for teaching infants.

Modern human characteristics

The substantial development of the brain in modern humans was accompanied by significant increases in using and making tools. Tool use is not a uniquely human trait; for example, Egyptian vultures (*Neophron percnopterus*) may break ostrich eggs by striking them with stones, while New Caledonian crows (*Corvus moneduloides*) strip the spiny edges of plant leaves to make hooks to lever insects out of their hiding places under bark. However, humans are unusual in the range of tools they use and in their ingenuity in fashioning or modifying tools for special tasks. These tools, especially those powered by fossil-fuel energy sources, give humans a great capacity to modify their environment.

Modern humans also display an outstanding facility with language, both spoken and written, and this is an important basis for learning to be passed on between generations. Language aids communication about the physical world and also expresses abstract ideas such as ethics, justice or evil. Throughout their lifetimes, but especially in their protracted period of dependence on their parents, humans learn both by observing others and also by sharing their experiences via language. As the playwright George Bernard Shaw observed, if you and I each have an apple and we swap apples, we each still have only one apple. However, if we each have an idea and we swap ideas, then each of us will have two ideas. The accumulation of this shared experience and its transmission from generation to generation is what makes up culture. It is a flexible, rapidly changing means of adjusting human responses to environmental change that considerably outpaces biological evolution. Language, both written and spoken, is a powerful medium for its transmission. Box 1.1 gives common characteristics of all human cultures.

Science and technology are important parts of human culture. Science involves solving questions raised by observations of nature, using reasoned evaluation of evidence and careful testing of ideas. Good science has a high success in predicting the outcomes of

Box 1.1 Common features of all human cultures

A detailed anthropological study published in 1945 listed 67 characteristics common to all known human cultures at that time. Culture was taken to mean the social behaviours and institutions of the societies. The list included:

> Age-grading, athletic sports, bodily adornment, calendar, cleanliness training, community organization, cooking, cooperative labour, cosmology, courtship, dancing, decorative art, divination, division of labour, dream interpretation, education, eschatology (myths about the beginning and end of time), ethics, ethno-botany, etiquette, faith healing, family feasting, fire-making, folklore, food taboos, funeral hospitality, housing, hygiene, incest taboos, inheritance rules, joking, kin groups, kinship nomenclature, language, law, luck superstitions, personal names, population policy, postnatal care, pregnancy usages, property rites, propitiation of supernatural beings, puberty customs, religious ritual, residence rules, sexual restrictions, soul concepts, status differentiation, surgery, tool-making, trade, visiting, weather control and weaving.[1]

More recently, other anthropologists suggested adding 'marriage customs' (not implying monogamy) to the list. Thus despite the unique features of individual cultures, there is still much in common between them.

[1] From Wilson, E.O. (1998). *Consilience: the unity of knowledge.* Vintage Books, New York and Little, Brown Book Group, London.

new situations, because of its sound understanding of underlying processes. Technology is the practical application of science in daily life, in which the understandings gained through science are used to solve problems or design new tools.

Human cultural development

Despite the diversity of human cultures, three broad stages of cultural development can be recognised: pre-agricultural, agricultural and urban. The transition from each caused a surge in human population numbers associated with improved food production (Table 1.1), but created a greater capacity to damage the environment.

In pre-agricultural cultures humans survived by gathering plants and hunting or scavenging animals for food. The domestication of plants for agriculture profoundly altered human lifestyles and their interactions with their environment by enabling protracted settlement in one place. In particular, urban living with very high population

Table 1.1 Human population growth and cultural development over the last 1 million years.

Years before present	Cultural development	Approximate density per square kilometre	Approximate population (millions)
1 000 000	Pre-agricultural	0.00425	0.6
30 000–40 000	Pre-agricultural	0.02	2.5
10 000	Pre-agricultural, first storage of wild grain	0.04	5
2000–9000	Village farming, early urban development	1.0	133
160	Intensive agriculture and industrialisation	6.2	906
Present	Modern technological	46	6300

densities became possible. Its potential was fully realised during the Industrial Revolution, when the replacement of cottage industries with large-scale, machine-based production concentrated workers in large urban centres. The new production techniques and living conditions created enormous demands for energy. This was supplied initially by timber and coal, and more recently by oil, natural gas and nuclear energy. The environmental interactions characterising these three stages of cultural development are shown in Figure 1.2.

Pre-agricultural ecosystems

Pre-agricultural ecosystems were characterised by solar energy input and by the large-scale recycling of matter. Humans lived entirely within such ecosystems for at least 100 000 years, subsisting by collecting plant foods, scavenging remains of animals killed by other predators and limited hunting. About 50 000 years ago humans developed more sophisticated weapons, enabling active hunting of large game. A detailed example of such a lifestyle is given in Box 1.2.

The environmental impacts of pre-agricultural lifestyles are controversial. Some anthropologists believe that aggressive scavenging by armed people could have driven large carnivores from their kills and depleted their food supply. Hunting methods such as driving herds of animals over cliffs wastefully killed large numbers, and the use of fire to flush out game altered plant ecosystems. It is argued that the development of more sophisticated weapons led to the hunting and ultimate extermination of a range of large animals including woolly rhinoceros, mammoths and giant deer in Europe, a range of large mammals in North America and large marsupials in Australia. Proponents of this view argue that human migrants carried the new hunting skills into previously unoccupied environments where the animals, unadapted to human predation, succumbed quickly. This is called the blitzkrieg hypothesis, after Nazi Germany's aggressive use of

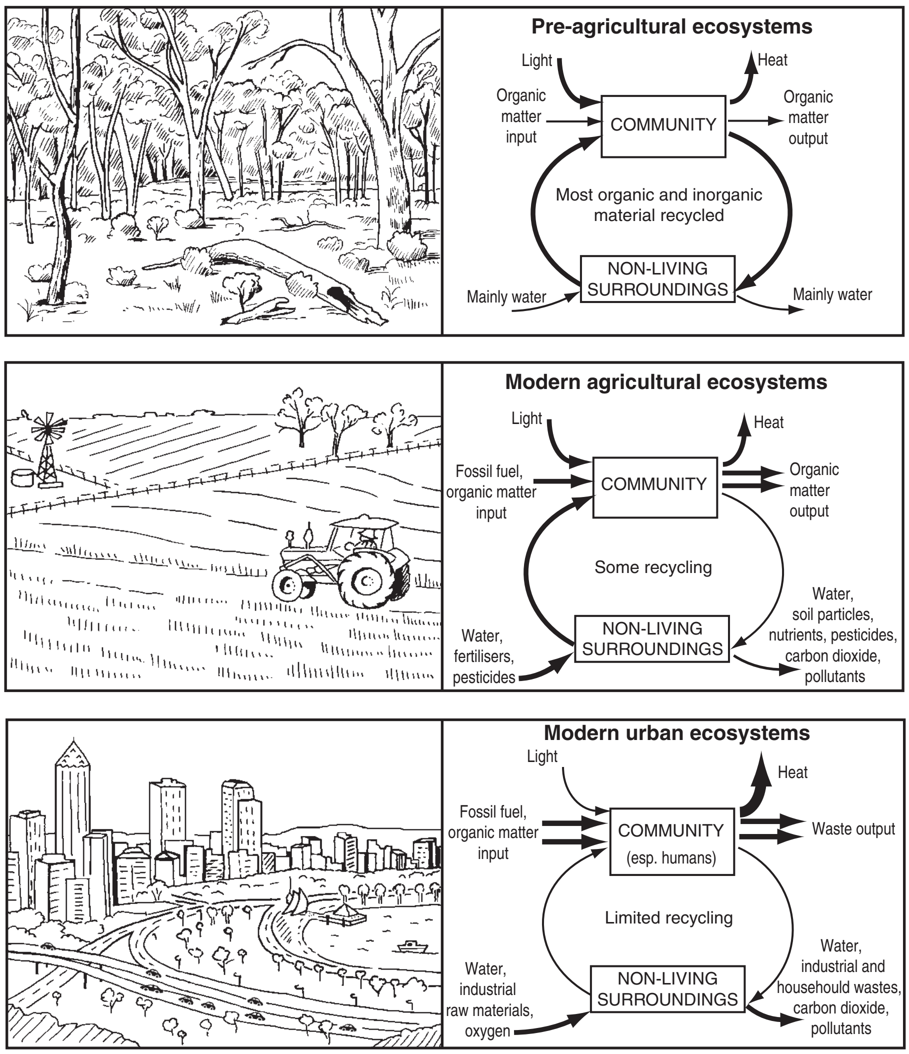

Figure 1.2 Characteristics of pre-agricultural, agricultural and urban ecosystems. (Source: Adapted from Morgan, D. (supervising editor) (1973). *Biological science: the web of life*. Australian Academy of Science, Canberra)

a novel combination of tanks and infantry to overrun opponents in early World War II. Some of these conclusions are debated fiercely, with alternative explanations such as climate change and disease proposed as sole or contributory causes of the extinctions. However, one case is reasonably free of controversy. The 11 species of New Zealand moas, flightless birds some of which stood up to 2 metres high at the shoulder, were hunted to extinction within 100 years of Polynesian settlement of New Zealand. Furthermore, the Polynesians introduced rodents that may have contributed to the extinctions by preying on moa eggs.

Box 1.2 The Martu of Western Australia – an example of a pre-agricultural culture

The traditional lands of the Martu people lie in the Pilbara, Western Australia. The average annual rainfall is 306 mm, with localised heavy falls. Many water sources are ephemeral, so the location and permanency of water is the major constraining resource.

Foods are widely dispersed and separately of poor quality. People choosing where to search for foods probably used a hierarchy of scales. In order from the smallest to the largest, these are:

1. selection within micropatches
2. targeting of some plant communities
3. use of particular landscapes
4. habitation of general regions.

Plant food comprised 70–80% of the diet. The people ate at least 106 of the 330 plants from the region, with 20–40 being staple foods. Their choice depended on:

1. abundance, predictability and access
2. the energy costs of processing
3. the energy and nutrient returns of species, and
4. cultural preferences.

Animals were eaten too – at least 12 species of mammals. Reptiles were a reliable food source.

The people used biological indicators such as cricket calls to predict resource availability. They recognised specific vegetation communities to gather plant resources, while hunters ranged more widely. Group size and pattern of movement over the countryside fluctuated with resource availability, and there was some evidence for species management (e.g. sowing seeds on burned ground).

These practices were specific to the region and we would expect variations elsewhere. Such ecosystems have solar energy input, heat output, and a little input and output of matter, with a high degree of recycling.

Agricultural ecosystems

The domestication of plants about 10 000 to 15 000 years ago improved the reliability of the human food supply and enabled people to settle in a single place for long periods. The sun remained the energy source, but inputs of matter such as manure or other fertilisers were needed to optimise crop production. The food and fibre produced were not necessarily consumed on site, some being traded with other communities. Thus, although extensive recycling took place, it was not as great as that occurring in pre-agricultural ecosystems. Early agriculture could have severe localised effects when vegetation was cleared to grow crops. Furthermore, the associated increases in population and the activities of domestic animals placed great demands on food production, leading

Box 1.3 Slash-and-burn farming – an example of agricultural ecosystems

(Contributed by Philip Ladd)

Slash-and-burn agriculture is an evocative term for an agricultural practice, perhaps less emotively termed 'shifting agriculture', first recorded about 8000 years ago in China. Today it is associated with clearing patches in rainforest in countries such as Papua New Guinea, Indonesia and Africa. However, it can also be practised in savanna and grasslands. Natural vegetation is felled, dried and burned to provide ash as a fertiliser. Crops are planted in the ash bed for several years afterwards.

Productivity is initially high because of the nutrients provided in the ash bed. However, many agricultural crops (especially the annuals, such as maize, taro and wheat) have high nutrient requirements and harvesting removes a large proportion of the nutrients accumulated in the plants, so they are lost to the system. Nutrients are also lost in erosion when heavy rains fall on cleared plots. Ultimately, depletion of soil nutrients, especially phosphorus, and increases in the acidity of the soil render it increasingly unproductive for crops, and the cleared areas are abandoned. The local native plants are adapted to the lower nutrient availability, reinvade the cleared areas and increase the biomass production when people move on. In some ways it is similar to a crop–fallow cycle in a more conventional farming system where crop paddocks are rested for 1 to 3 years between crops. If only small plots are disturbed in large tracts of forest, the environment copes with the disturbance, but when the proportion of disturbed ground to forest increases problems arise.

Agricultural systems such as this have inputs of solar energy, water and natural fertilisers. Organic matter and mineral nutrients are removed by both crop plants and erosion. Modern intensive agriculture greatly increases inputs of chemical fertilisers, fossil fuels for energy, water from irrigation and pesticides to give greater crop yields.

in some cases to land degradation and loss of productive capacity. An example of such an agricultural culture is given in Box 1.3.

Despite these problems, the food stores generated by agriculture allowed greater division of labour in human societies. Fewer people were involved directly in food production, freeing others for different activities. Cultures were enriched and the pace of innovation increased.

Urban ecosystems

The concentration of people in cities characteristic of the modern world was stimulated by the Industrial Revolution that began in the late 18th century. The development of machines ended the localised cottage industries of earlier times and shifted production of goods into the mechanised factories of the cities. Machines also transformed agriculture and, because of the lower demand for agricultural labour, people migrated to cities in