1

Ecological monitoring

1.1 Introduction

The purpose of this chapter is to introduce the reader to the concept of monitoring ecological change and to some ecological monitoring programmes. Monitoring ecological change has considerable relevance at a time when humans are having an increasingly widespread and long-term impact on nature. I have drawn on personal experiences in defence of the value of ecological monitoring (to conservation and sustainable development) and also the value of long-term ecological research.

1.2 Terms and concepts

The aim here is not to undertake academic discussions about definitions. It is, however, necessary to distinguish between the various terms as used in this book. Recording, mapping, surveys and sampling are all methods of data collection that provide a basis for monitoring, that is the systematic measurement of variables and processes over time.

Census

The term census generally refers to population counts, which, in turn, can be used in monitoring programmes.

Surveillance

Surveillance is the systematic measurement of variables and processes over time, the aim being to establish a series of data in time.

Monitoring

Monitoring is also the systematic measurement of variables and processes over time but assumes that there is a specific reason for that collection of data, such as ensuring that standards are being met.

In a report of the Study of Critical Environmental Problems (SCEP, 1970) entitled *Man's Impact on the Global Environment*, there is a similar definition of monitoring: 'systematic observations of parameters related to a specific problem, designed to provide information on the characteristics of the problem and their changes with time'.

Ecological monitoring is, therefore, about the systematic collection of ecological data in a standardized manner at regular intervals over time. Some organizations and people recognize or have established different types or categories of monitoring. For example, the Department of Conservation in New Zealand recognizes three types; result monitoring, outcome monitoring and surveillance monitoring (Box 7.1, p. 224).

In another example, Vaughan *et al.* (2001) have described four categories of environmental monitoring:

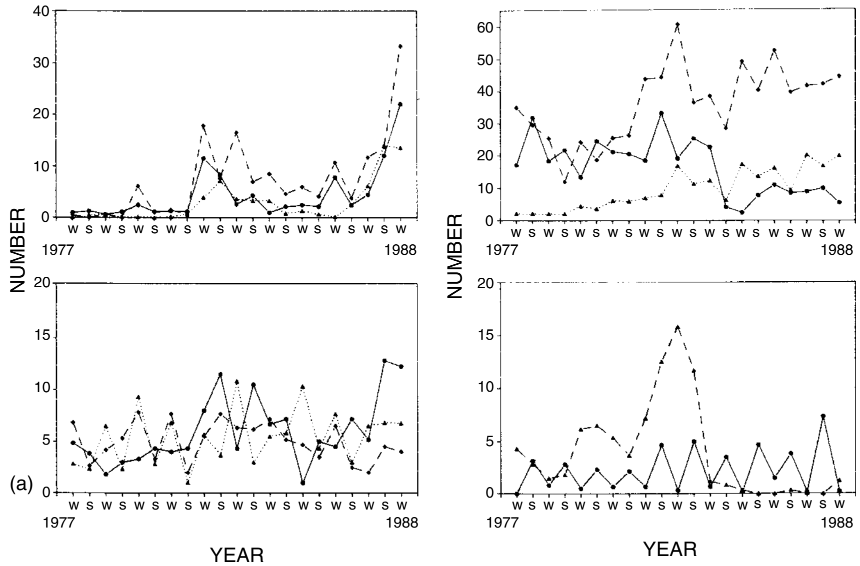
- simple monitoring: recording the values of a single variable at one point over time
- survey monitoring: the absence of an historical record for an environmental problem in a particular area can be replaced by a survey of the current environmental conditions in both the affected area and the area not affected
- surrogate or proxy monitoring: compensating for the lack of previous monitoring by using surrogate information to infer changes
- integrated monitoring: using detailed sets of ecological information.

Three examples of ecological monitoring are shown in Box 1.1. The first example shows temporal changes (10.5 years) in desert rodents; the second example comes from an estuary monitoring programme where levels of effluent have decreased and the final example is based on experimental planted grassland communities.

All examples serve to introduce the concept of monitoring ecological change. At the same time, these examples prompt some interesting questions and issues. The first example uses data from captured individuals and data are expressed simply as population size. Is the size of the captured population an indication of the total population size? In the second example there has been management of the pollutants entering the marshland community. While the data show decreased levels of pollutants and increased abundance of plant communities, there remains the challenge of demonstrating cause and effect.

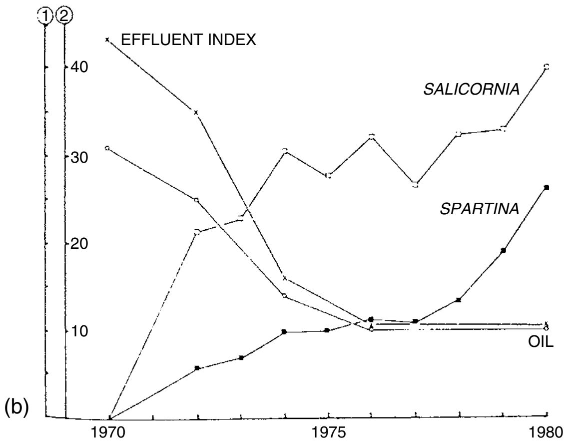
Box 1.1 Examples of ecological monitoring

Example A



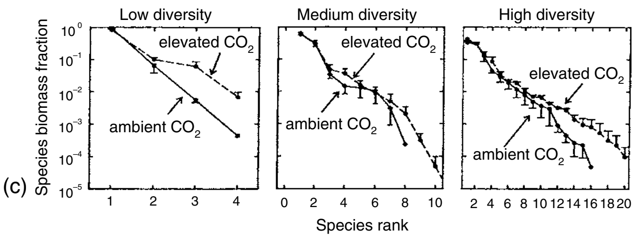
Population dynamics of 11 common rodent species at a Chihuahuan study site over 10.5 years. Numbers are given as six-month averages for summer (S) and winter (W). Left, murid rodents; right heteromyid rodents. (With permission from Brown & Heske, 1990.)

Example B



Comparison of effluent quality index, the area of damaged marsh recolonized by *Spartina* and *Salicornia* spp. (as a percentage) (vertical axis 1) and oil content (ppm) (vertical axis 2 between 1970 and 1980. (With permission from Dicks & Iball, 1981.)

Example C



Plant species dominance at ambient and elevated CO_2 in plots of differing plant species diversity. (With permission from Niklaus *et al.*, 2001.)

The third example describes some experiments with planted grassland communities and elevated levels of CO_2. The authors make the observation that short-term effects may be misleading when attempting to predict long-term effects (Niklaus *et al.*, 2001).

Sampling, recording, mapping, surveying, inventories and long-term ecological research can contribute to ecological monitoring. Regular counts or census of a population of birds can form the basis of ecological monitoring – or monitoring ecological change in the bird populations. For example, Dunwiddie & Kuntz (2001) described long-term trends of the Bald Eagle in winter on the Skagit River, Washington, based on data from weekly counts between 1978 and 2000. Peak one day counts varied from 77 in 1983–1984 to 506 in 1991–1992.

Surveillance is also the systematic measurement of variables and processes over time, the aim being to establish a series of data in time. Similarly, monitoring is the systematic measurement of variables and processes over time but assumes that there is a specific reason or objective for that collection of data such as ensuring environmental standards are being met. The 1970 SCEP report carried a similar definition of monitoring (see p. 2).

Phenology has some relevance to ecological monitoring. It is the study of the times of recurring natural events: a calendar of nature's events. For examples the date on which the first salmon reappear, when frogs first arrive at a pond or when the first spring wild flowers bloom.

Recurring events in nature have long been recorded and some records go back many centuries. In the UK, phenology was well recognized by 1875 when the Royal

Meterological Society established a national recorder network. Later, in the 1990s, a pilot scheme for a phenology network was established at the Centre for Ecology and Hydrology (CEH) in Cambridge. In 2000, the UK Woodland Trust together with the CEH launched a project to promote phenology. Now, many thousands of people from around the UK are registered on-line with the phenology network.

How exciting it would be to see similar activities in many other countries. At the same time there needs to be care with the analysis of any changes that may be detected in reoccurring natural events. For example, although climate warming may appear to be affecting the seasonal behaviour of some amphibian species, such conclusions may be premature (Beebee, 2002).

1.3 Why ecological monitoring?

Ecological monitoring has to be resourced and financed. There may be long-term resourcing implications and some ecological monitoring can be relatively expensive. What, if any, is the justification for ecological monitoring? Four reasons come to mind.

1. The processes of many ecosystems have not been well researched and monitoring programmes could provide basic ecological knowledge about those processes.
2. Management of ecosystems, if it is to be effective, requires a baseline, which can only come from ecosystem monitoring.
3. Anthropogenic perturbations on the world's ecosystems have long-term effects, some synergistic and some cumulative: therefore, it follows that long-term studies are required.
4. The data from long-term studies can be a basis for early detection of potentially harmful effects on components of ecosystems.
5. With the ever-increasing loss of species, loss of habitats and damage to biological communities, ecological monitoring is needed to identify the implications of these losses and damage.

Interestingly enough, the reports to the US National Science Foundation (NSF) regarding long-term observations of ecosystems made similar recommendations for the data that could be obtained and the nature of the measurements: that such data could concern:

- cyclic changes
- time lags in ecosystem responses to outside influences
- test of ecological theories concerning stability, community structure and system development
- sensitive indicators of ecological change.

There are international pressures and requirements for environmental and ecological monitoring. For example, many countries have signed international conventions and agreements (e.g. the 1992 Convention on Biological Diversity (see the Appendix) and the Montreal Process) and consequently there is a requirement for monitoring to take place and for respective countries to report on that monitoring. That monitoring could range from forest cover and condition through to population levels of marine organisms as a monitor of carbon stocks (Coomes *et al.*, 2002).

The Convention on Biological Diversity (Appendix), draws attention to the need to identify and monitor ecosystems, habitats, species, communities, genomes and genes. Article 7 of the Convention is about identification and monitoring. However, it is not possible nor practical to monitor all species, communities and ecosystems. Therefore, there has to be some kind of prioritization. There are criteria for prioritizing ecosystems, habitats, species and communities for ecological monitoring (see p. 229). Priorities for monitoring biological diversity have also been drawn up by the United Nations Environment Programme (UNEP, 1993).

Within some countries, there may also be national requirements for monitoring, particularly with regard to environmental management and reporting the state of the environment. Many countries have established legislation requiring certain standards of environmental quality and in most cases the legislation is enforced mainly to prevent unacceptable levels of pollution and to ensure appropriate quality of the environment. In New Zealand, the 1992 Resource Management Act has the purpose of promoting sustainable management of natural and physical resources with the emphasis on the effects of activities on the environment. Environmental monitoring or surveillance is required to determine those effects.

Whether or not there is a legal requirement, management of nature resources and services cannot take place successfully or in a sustainable manner unless we know what is happening. Ecological and environmental monitoring is, therefore, a prerequisite for environmental management and sustainable development.

Ecological monitoring and research are intertwined. For example, the relevance of environmental monitoring to research and environmental management was highlighted in a 1992 discussion document produced by the Scientific Committee on Antartic Research (SCAR) and the Council of Managers of National Antartic Programmes (COMNAP).

> Environmental monitoring is a fundamental element of basic research, environmental management and conservation. The organized and systematic measurement of selected variables provides for the

establishment of baseline data and the identification of both natural and human-induced change in the environment. Monitoring data are important in the development of models of environmental process, which in turn facilitate progress towards a predictive capability to detect environmental impact or change . . . .

1.4 Personal reflections and experiences of ecological monitoring

I have included the following because it provides a context for the material that I have selected for this book. It reveals some details about me and hints as to the bias that has been adopted in this book.

During the 1980s, I often advocated that marine, aquatic and terrestrial 'sites' should be set aside as long-term ecological monitoring sites to provide baseline information. The questions most commonly asked of me were: 'What would be the purpose of such sites?' 'Why monitor the ecology of a site?' I believed that such sites would provide baseline data and the important background information for measuring change in biophysical conditions and that such sites could be used to assess any improvement or degradation in the state of the environment. How else would it be possible to distinguish between natural ecological changes and those changes brought about by human impacts? I was not advocating monitoring for the sake of monitoring. There was a specific reason and application for the proposed ecological monitoring.

In 1986, I established the basis for a long-term ecological monitoring site on a private nature reserve in the south of England. Unfortunately, that project was not supported and did not continue.

On a Monday evening, 21 April 1986, I chaired the usual weekly environmental sciences seminar for students at the University of Southampton. That evening, our guest speaker was an expert on energy and he spoke very strongly about the importance of nuclear power and talked much about its safety record. By the following Monday, the news had broken about the Chernobyl nuclear accident, which took place in the Ukraine on 26 April. The contamination spread northwest over Europe and affected many areas including the grazing land in Wales and the west of England. For many years after, the affects of the contamination were observed in the grassland ecosystems.

The purpose of this story is not about the benefits or dangers of nuclear power. Before Chernobyl, the idea of establishing long-term ecological monitoring sites to assess the state of the environment for the purpose of background or baseline information was not widely supported. Then, all of a sudden, throughout western Europe there was a realization that there was little or no background or baseline information on which to base comparisons or identify human-induced changes. Concern was expressed about the effects of radiation on agricultural ecosystems including grazing lands in parts of the UK such as the Welsh uplands.

Does it always take an environmental disaster to put theory into practice? Perhaps not; but I cannot help but suspect that ongoing changes in the biophysical environment have had a significant role to play not only in heightening concern about the state of plant and animal populations and communities but also in helping to win more support for the need to have long-term ecological monitoring sites. But where should those sites be?

If there was to be only one biogeographical region that was to be used for monitoring the state of the Earth and changes in the biophysical environment, it could be the polar regions. Since the early 1990s, the media have reported the shrinking of ice caps, the appearance of open water at the North Pole, and huge icebergs breaking off from the Antarctic ice shelves. Whatever the cause, these events clearly demonstrate that changes are taking place, even in those regions such as Antarctica that are relatively remote from human impact. Or should that be remote from *direct* human impact?

1.5 Priority areas for ecological monitoring

Thinking globally, considering all the Earth's biogeographical regions, are there areas that should be a high priority for ecological monitoring? The answer of course depends on what the objectives are. It could be argued that ecological monitoring needs to occur in:

- regions where there are greatest impacts caused by humans so that the effects of land use can be managed in a sustainable manner
- regions not greatly affected by humans so that baseline information can be obtained; this would include biological communities for which there were comparable communities that had been affected by human activities
- regions where there has previously been little ecological monitoring but where we need to know if environmental degradation does occur; for example, there, ranging from sites around effluent discharges to deep-sea locations, that are many marine regions could justifiable be subject to ecological monitoring programmes.

There is one region that would at first sight seem remote from human impacts yet has a central role in global environmental processes: this is the Antarctic region. This region includes a great ice-covered land mass and biologically rich oceans would appear to be a region and that is relatively safe from

Table 1.1 *Some environmental impacts (deliberate, incidental or accidental) in the Antarctic*[a]

Area	Impacts
Terrestrial (including inland waters)	Habitat destruction/modification
	Destruction/removal/modification of biota, fossils, ventifacts, etc.
	Modification of vital rates of biota (disturbance to production and/or growth)
	Modification of distribution of biota
	Introduction of alien biota
	Pollution by biocides and noxious substances, nutrients (eutrophication), radionuclides, electromagnetic radiation, noise
	Modification of thermal balance of environment
	Aesthetic intrusion
Marine (including shoreline, enclosed waters, benthos)	Habitat destruction/modification
	Destruction/removal/modification of biota
	Modification of vital rates of biota
	Pollution by biocides and noxious substances, nutrients, radionuclides, inert materials (dumping), noise, heat
Atmospheric	Pollution by sulphur oxides, nitrogen oxides, carbon monoxide, carbon dioxide, hydrocarbons, radionuclides, dusts, microbiota, electromagnetic radiation
	Ozone: local excess at ground level, depletion in stratosphere

[a] Some very unlikely impacts and impacts of negligible severity have been ignored.

exploitation and sufficiently remote not to be harmed by pollution. The Antarctic region might also be considered to be one of the last locations on earth where there was a need to undertake any kind of monitoring or surveillance of the wildlife. However, as long ago as 1985, there were reports on the impacts of human activities in the Antarctica (Table 1.1).

For over 200 years, the southern oceans (the broad band of water that circles the southern hemisphere between latitude 40° and Antarctica) have been exploited for whales, fish and plankton. Pollutants from the industrialized world have reached and penetrated the Antarctic ecosystems and the operational activities of Antarctic research and exploration have had their deleterious impact on the coastal populations of birds and mammals (Bonner, 1984; Wilson *et al.*, 1990). Supply ships have spilled petroleum fuel in Antarctica and sadly we know very little about the way in which oil pollution affects ecosystems in polar regions.

During the 1950s, a number of scientific programmes were established in relation to research on global environmental change. The International Geophysical Year of 1957 was a landmark in this respect and marked the establishment of environmental monitoring in Antarctica. During the 1960s, there was a considerable increase in research alongside a greatly increased support for environmental, especially geophysical, investigations. Antarctic biological research has long included a wide programme of activities, some of which have been directed at population ecology of mammals and birds. For example, surveillance and census of seals, penguins and other birds has been undertaken for many years but few results from that surveillance and census work will make any significant contribution to any Antarctic conservation strategy. This is because the data have not been collected in a systematic and standardized manner and because of the lack of an infrastructure for long-term ecological monitoring. This is a missed opportunity, of which I have had some small personal experience.

It was during the 1960s that I was a member of a research team in Antarctica and part of my research included an analysis of the population ecology of the Adélie Penguin (*Pygoscelis adeliae*) and the McCormick Skua (*Catharacta maccormicki*). The populations of these two birds were occasionally recorded in the area of Cape Royds, Ross Island, as part of an ongoing surveillance programme. My field work over three years was a very small contribution to the population records that had been kept before the 1960s and that continue to be maintained.

At that time, there seemed to be little concern about the potential value of data from the census of those birds, especially where it was to be undertaken on a systematic basis. Although we saw the value of those records as providing a 'watchful eye' on the status of the populations, no one seemed to be sure of any long-term objectives of the surveillance programme. The recording was not administered so as to ensure continuity: records were not kept in a central depository and recording methods were not uniform.

During that time (1960s), the logistical and research activities had various impacts on the Antarctic birds in and around the area of Cape Royds. Helicopters bringing tourists to the area regularly flew close to penguin colonies, causing havoc. Perhaps not surprisingly, the people involved in the research were concerned even if the helicopter flight was on a mercy mission (Box 1.2).

There was one occasion when I recorded what appeared to be an outbreak of disease amongst the skuas. Birds were observed dying. Throughout each summer, there would always be a few dead skuas found in the study area. On this occasion, the incidence of death had greatly increased. It is always difficult to demonstrate cause and effect. One possible contributing factor may have been the fact that rubbish from the large bases nearby attracted scavaging skuas. Could the birds have been poisoned or contracted some kind of disease?