PART I
Setting the scene

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Exploitation as a conservation issue

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People have exploited wildlife throughout their history and even in ancient times this activity is known to have caused the extinction of many species. Today's exploitation pressures are massively more severe than in the past for several reasons. The human population now exceeds 6 billion globally, and people impact on every part of the Earth's land surface and increasingly on the oceans and atmosphere. Current estimates suggest that about 40% of all the earth's primary productivity is harnessed for human use (UNEP, 2000). As Figure 1.1 illustrates, rapid population growth is a feature most evident in the last century and growth is expected to continue for hundreds of years into the future (UN, 1998). These high population numbers are permitted by our technological developments, which enable us to exploit natural resources with rapidly increasing levels of efficiency, against which the natural defences of wild species are hopelessly inadequate. Alongside this, progress in transportation and communications allows people to travel further and occupy more areas that once provided refuges for wild species.

The result of escalating human populations and increased intensity of our consumption of natural resources is that exploitation (or harvest) of wildlife represents a major threat to many of the world's plant and animal species. For birds and mammals it is second in importance only to habitat degradation as a cause of threat (WCMC, 1992; Hilton-Taylor, 2000) (Figure 1.2). Various forms of exploitation have been implicated in species declines, including commercial and subsistence hunting, extraction, collecting activities and the impacts of trade. These population declines can have severe economic and social impacts in activities ranging from subsistence hunting of bushmeat to large-scale commercial fisheries. In Figure 1.3 we present decline data for some marine species; these kinds of trajectory are now common among terrestrial plants and animals, although we rarely have adequate data to document them so closely. Attitudes to continuing declines of once widespread species are quite different in the

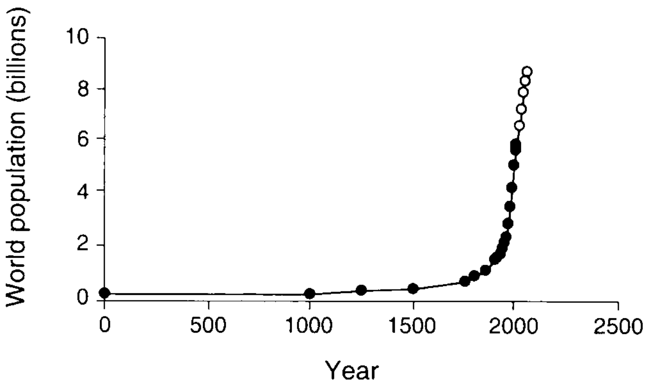

Figure 1.1. World population trends for humans, including projections to the year 2050. Shaded circles are past population estimates and open circles are future projections. (From UN, 1998.)

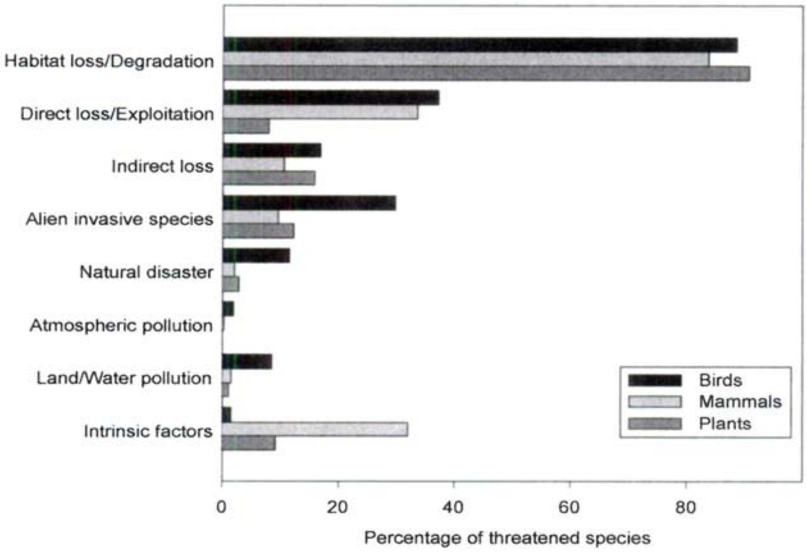

Figure 1.2. The major threatening processes affecting birds, mammals and plants listed in the IUCN *Red List of Threatened Species* (Hilton-Taylor, 2000).

conservation and resource management literature. While declines may be regarded by resource managers as an inevitable consequence of a managed harvest, conservationists may see them as a serious threat to populations (Mace & Hudson, 1999). Here we explore this dichotomy of views in a little more detail to ask when declines should become a conservation issue.

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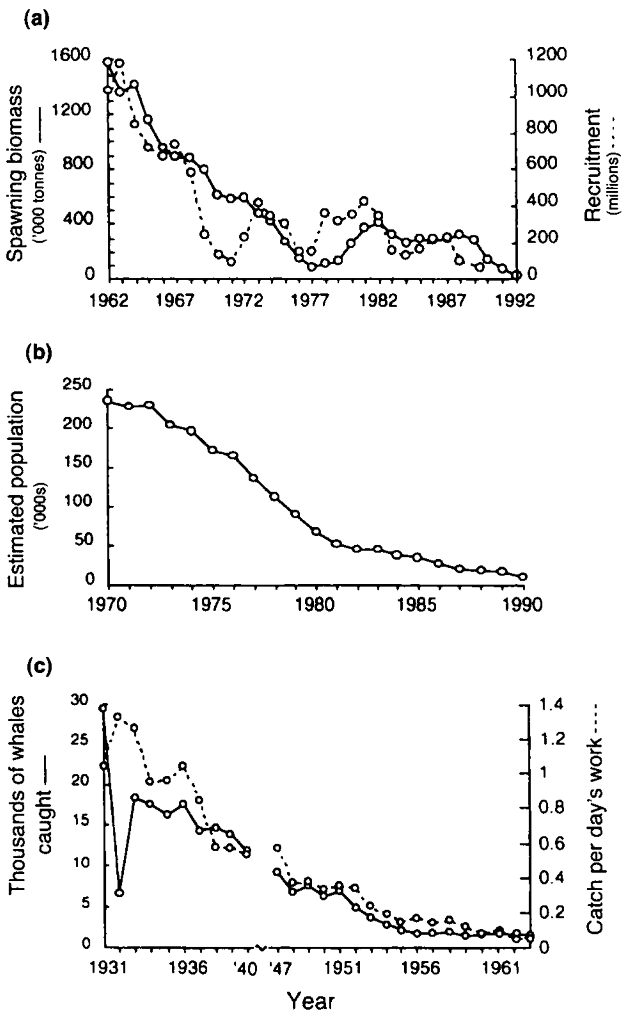

Figure 1.3. Population declines of three species of exploited animals. (a) Northern cod stock *Gadus morhua* off eastern Canada. Spawners are at least seven years old and recruits are three years old. (b) Western Atlantic bluefin tuna *Thunnus thynnus*; (c) blue whales *Balaenoptera musculus* in the Antarctic. Numbers caught are shown by the solid line and numbers caught per hunter-day's work are shown by the broken line. (Figure and original references from Reynolds & Jennings, 2000, with permission from Cambridge University Press.)

Broadly speaking, this book asks why overexploitation occurs, and what might be done about it. We should be heartened by the fact that sustainable exploitation is central to much current conservation policy. The *World Conservation Strategy* (IUCN/UNEP/WWF, 1980) and its successor, *Caring for the Earth* (IUCN/UNEP/WWF, 1991) emphasise the way in which sustainable human livelihoods will depend upon prudent use of natural resources, including wild species. In understanding the dynamics of harvesting, we can draw on experience from a long history of research into sustainable exploitation. This work has led directly to many of the key concepts that feature in modern theories of ecology and population biology (for a review, see Milner-Gulland & Mace, 1998). Given the extent of this effort, one might wonder how we could run into problems with overexploitation. There are two obstacles. First, despite extensive research into methods for harvesting natural populations in a sustainable manner, there are still many biological difficulties in estimating key parameters and predicting the consequences of management regimes. Secondly, even if we can get the biology right, there are usually severe difficulties in implementing and enforcing management plans. Thus, conservation of exploited species represents a considerable biological and social challenge.

In this chapter we ask three questions about the conservation of exploited species: (1) what are the goals of exploitation? (2) Why is sustainable exploitation so difficult? (3) What are the characteristics of vulnerable species? We conclude with a brief set of suggestions for successful conservation of exploited species.

WHAT ARE THE GOALS OF CONSERVATION AND EXPLOITATION?

Goals for conservation and exploitation can be divided into those that relate to our attitudes to nature, and those that determine what it is we are trying to sustain.

Attitudes to nature

At the broadest level, people vary in their attitudes to nature and natural resources. These views can be presented along a continuum which encompasses two extreme positions. On the one hand, we characterise a 'preservationist' attitude, where the goal is to preserve nature in its current state (or perhaps a historical state). This attitude views exploitation by humans as artificial and undesirable. On the other hand, we characterise a 'hit-and-run' attitude, where the goal is to maximise returns from nature, with no desire to maintain or sustain any natural resources. Clearly, to most people,

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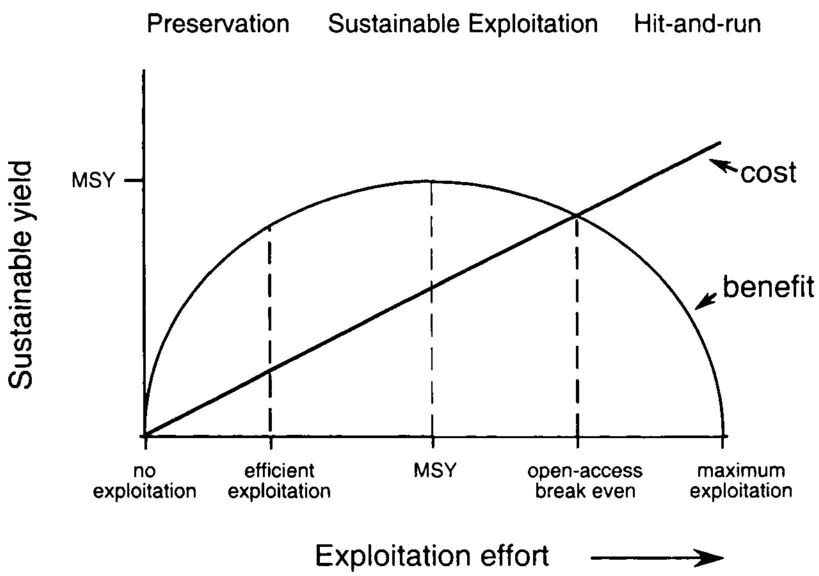

Figure 1.4. Attitudes to nature, shown across the top of the figure, reflect differing goals of exploitation. Exploitation effort increases along the *x*-axis, ranging from 'no exploitation' stemming from a 'preservation' goal at one end of the continuum to 'maximum exploitation' stemming from a 'hit-and-run' goal at the other. The *y*-axis measures the sustainable yield that results from any level of exploitation of a population. MSY, maximum sustainable yield.

these extreme positions are both absurd and indefensible, but the continuum between them is real and an important backdrop against which to consider sustainable use.

A schematic diagram (Figure 1.4) illustrates these attitudes superimposed on a simple, classic formulation that relates costs and benefits to exploitation effort. Here, as exploitation effort increases, the yield first increases as a consequence of reduced density dependence in smaller populations leading to higher productivity. Yield then declines as the population becomes too small (for a review, see Ludwig, Chapter 2). Maximum sustainable yield (MSY) is achieved at an intermediate level of exploitation. However, the costs of exploitation increase linearly with the level of exploitation. Levels of exploitation below MSY may result in lower yields but the investment required to exploit the resource is lower and there is a point of 'maximum efficiency' where the difference between cost and benefit is maximised (Figure 1.4). At levels of exploitation above MSY there are declining benefits and increasing costs. The level of exploitation at which costs equal benefits is the break-even point, where any further increase in exploitation will result in net losses. This may be characteristic of exploitation of open-access resources. A 'hit-and-run' attitude to nature may lead to maximum exploitation whereby one 'liquidates the resource' and invests the profits to maximise economic gain from an extinct population, as discussed by Donald Ludwig (Chapter 2). Obviously, people with such goals cannot be considered conservationists, but conservationists need to understand them if they are to win the argument with their own goals.

Figure 1.4 thus shows how different goals ranging from preservation to hit-and-run can be met by different amounts of exploitation. These goals need to be set out clearly before we can debate the success or failure of conservation programmes that involve exploited species.

What are we trying to sustain?

The second kind of goal relates to what, exactly, we are trying to sustain. Are we interested in sustaining populations, species, ecosystems or human communities? These differing goals are discussed in the closing chapter of this book by John Robinson, who notes that different goals are implicit in different species' harvesting programmes, but these are rarely made explicit. Yet they affect the currencies that are plotted in Figure 1.4. For economists, the yield and costs curves might represent money; to a member of the Yuqui of Bolivia, the gain curve might represent kilograms of bushmeat and the loss might represent time and energy; a community ecologist might view the functions as gains or losses in biodiversity.

Most of these differing goals are covered by different chapters in this book. Maximisation of yields from single species has been the traditional goal of temperate fisheries, as reviewed by André Punt & Anthony Smith (Chapter 3). Thus the dome-shaped function in Figure 1.4 is usually measured in biomass of species X harvested over the long term, which is usually considered in terms of about a decade. Extinction almost never enters into the equation. In contrast, Russ Lande and his co-authors (see Chapter 4) confront extinction directly and suggest that the most prudent and long-term goal is to maximise the cumulative harvest before extinction occurs. In their analyses the yield curve thus explicitly refers to sustainability over thousands of years – far longer than any commercially based natural resource managers would consider relevant.

Perhaps the target species and the revenues and products to be gained from it are not the currency of interest. Many biologists are more concerned about communities and ecosystems. Michel Kaiser & Simon Jennings (Chapter 16) describe the wide variety of responses that communities may undergo in response to reductions in targeted species. Some measure of biodiversity might therefore replace the single-species yield curve in Figure 1.4, though its relationship with exploitation effort will not be straightforward. Some marine food webs have proved to be quite resilient against the loss of individual species, whereas others have shown dramatic effects, as have various freshwater and terrestrial communities. Kent Redford & Peter Feinsinger (see Chapter 17) have a similar currency in mind, though they are concerned with processes that are more subtle than the predator–prey relationships usually considered in 'multispecies' approaches to exploitation. They consider the potential for dramatic effects of processes resulting, for example, from disruptions to interactions between plants and pollinators, or frugivorous birds and the plants that rely on them for dispersal. Hence their metaphor of a 'half-empty forest' – the species are still there for the time-being, but their interactions are disrupted in ways that may reduce populations in the future.

Goals based on human social and economic development may be a long way from the objectives of single-species or ecosystem sustainability. Two authors (Ludwig, Chapter 2; Sanderson, Chapter 21) discuss this issue in general terms but Jon Hutton & Barney Dickson (Chapter 20) explicitly assess the success of southern African conservation strategies for large mammals in terms of the livelihoods and economic consequences for the human communities involved. Indeed, they evaluate the success of various programmes on the basis of economics rather than direct measures of plant or animal population sizes, and objectives in that chapter can be achieved without maintaining species diversity. However, from a pragmatic viewpoint, the authors argue that we will lose species anyway, and present their case as the best from among difficult possibilities.

We believe that disagreements over goals cause most of the debates about sustainable exploitation, especially for charismatic species. As Steven Sanderson makes clear, this is a political discourse that cannot be ignored. We do not seek to resolve what the goals of sustainable exploitation could or should be. Rather we point out that the lack of clarity has led to unproductive debates that have compared the merits of apples versus oranges.

WHY IS SUSTAINABLE EXPLOITATION SO DIFFICULT?

Problems that hamper efforts to exploit wild populations sustainably can be divided into limits to biological knowledge and limits to control.

Limits to knowledge

Theoretical models of exploitation include some of the most sophisticated models of population dynamics that have been produced. Fisheries biologists and terrestrial ecologists routinely produce age-structured models that can incorporate a huge number of parameters concerning life histories, behaviour and ecology. Yet we never seem to know enough.

Parameter estimation is a troubling issue for many authors in this book. John Reynolds and collaborators (Chapter 7) resort to using simple life history characteristics to develop 'rules of thumb' for predicting responses of understudied fish populations to exploitation. William Sutherland & Jennifer Gill (Chapter 12) worry about the effect of density dependence on measurements of rates of population increase, and Jon Hutton & Barney Dickson (Chapter 20) rule out measuring population parameters for most African mammals that are subject to hunting. But there are more optimistic contributions to the problems of parameter estimation, and especially progress with methods for dealing with uncertainty. Paul Wade (Chapter 6) shows how we can incorporate uncertainty directly into parameter estimation as well as in making management recommendations. So, if we cannot measure all of the parameters we would like, at least we should work towards formal procedures for admitting this uncertainty into our analyses.

Another limit to knowledge involves the status of the population and the rate at which it is being exploited. Direct censuses of most exploited populations are extremely difficult, time-consuming, and expensive. One might think that counting caribou in an Arctic environment would be relatively straightforward, but Anne Gunn (Chapter 19) shows that the costs and practical issues involved make this impossible. While large-scale activities such as commercial fisheries provide large-scale data and funding for research, this is the exception rather than the rule.

Even if we can estimate our model parameters and census the populations, it is often very difficult to predict the future with any confidence. Environmental stochasticity is a fact of life for most animal populations, as illustrated for kangaroos by Gordon Grigg & Anthony Pople (Chapter 18), and for caribou by Anne Gunn (Chapter 19). Russ Lande and colleagues (Chapter 4) show how stochasticity can be successfully incorporated into models, but the problems of projecting into the future remain. This severely hampers long-term forecasts and management advice.

Limits to control

The 'tragedy of the commons' looms large in most discussions of the difficulty of controlling exploitation of wild populations. Understandable selfinterest leads individuals to exploit wild populations well beyond the MSY towards the break-even point (Figure 1.4). Thus we overexploit in the present rather than leaving individuals and their offspring to be exploited by others.

There are also mismatches between human and biological scales, both spatial and temporal, which can make exploitation risky. For example, political and economically driven management plans are likely to operate on a cycle length of a few years at most, whereas the precautionary approaches discussed by Russ Lande and co-authors (Chapter 4) require much longer time scales. Even more problematic for reliable implementation is the fact that these precautionary methods would call for irregular and hard-to predict periods when no exploitation would be permitted. Lande *et al.* discuss this problem and possible approaches to dealing with it, but it is clear that such methods will be vulnerable to the difficulty of reducing or stopping exploitation when human needs preclude such an approach.

Spatial mismatches also create risk-prone situations for certain species. In marine environments especially, but in terrestrial environments as well, species may range over areas controlled by different management authorities. Under these circumstances, the species will always be vulnerable to the lowest standard of management. Another spatial risk factor demonstrated by E. J. Milner-Gulland (Chapter 5) occurs when the distribution of hunters relative to that of the prey has a significant impact on the species' vulnerability that would not be detected without detailed records and sophisticated analyses.

Ultimately, limits to control are about social and political context and the implementation of regulations and plans. Various social and economic factors can increase problems with enforcement. Gordon Grigg & Anthony Pople (Chapter 18) describe the difficulties and tensions when dealing with a species that can be viewed as a pest or a resource, and yet is at the same time a focus for concern of animal welfare groups. Anne Gunn's case study of caribou (Chapter 19) shows how cultural tensions and differences can jeopardise what could be relatively straightforward management issues. The problems of distrust and poor communication between authorities, scientists, managers and hunters is a general one, though especially clearly presented in this case. Jon Hutton & Barney Dickson (Chapter 20) also emphasise the importance of community involvement in management decisions and they especially make the case that there should be direct and transparent links between economic gains from the species and benefits to the community. In this context, Steven Sanderson's analysis of the politics of exploitation is especially significant (Chapter 21). These chapters reflect a