This book is dedicated to Ione and Thomas,
as representatives of the next generation

Conservation of Biological Resources

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second year in prison is valued less highly than the first. To a person with a short time-horizon, 10 years in prison may look exactly the same as 5 years. This discounting, together with the empirical evidence, suggests that with a limited budget, it could be better to concentrate on increasing the perceived probability of detection than to spend the same amount on keeping people in prison for long periods.

Natural resource users' attitudes to law enforcement have been little studied. Sutinen and Gauvin (1989) showed that the rate of violation of regulations by lobster fishermen in Massachusetts varied with the perceived probability of detection and conviction, as predicted by the theory. Freehling and Marks (see Chapter 10) show how hunter behaviour in the Luangwa Valley, Zambia, has changed as law enforcement has increased. They now tend to use less easily detected snares, rather than guns, and are more secretive in their consumption of meat. Simple bio-economic models of harvesting can be altered to incorporate the risk of capture and a fine into the costs of harvesting (Sutinen & Anderson 1985). Mazany *et al.* (1989) modelled the likely extent of illegal fishing in a situation where there was a legal fishing quota, with imperfect enforcement. People who fish above their quota face an expectation of a fine, expressed as the fine received multiplied by the perceived probability of receiving it. The poacher's short-term profit-maximisation (in an open-access situation) then becomes:

$$\max_E[pH - cE - \theta\mathfrak{I}] \tag{3.1}$$

where p is the price per unit of output, H; E is all the inputs to production, not just effort; c is the cost per unit input; and θ is the probability of receiving the fine $\mathfrak{I}$. θ is assumed to depend on the amount of input E. $\mathfrak{I}$ can be expressed as a function of either input or output. The profit-maximising condition found by Mazany *et al.* (1989) for Equation 3.1 was:

$$pH_E = c + H_E[\theta_H\mathfrak{I} + \mathfrak{I}_H\theta] \tag{3.2}$$

where H_E means the partial differential of H with respect to E. This is equivalent to the profit-maximising condition found for the standard model ($pH_E = c$, Equation 1.8), but with the addition of a term for the marginal change in the expected fine with a change in the output H. The long-term profit-maximisation of a monopoly hunter can be generalised in a similar way, by adding the expected fine as a second cost term in Equation 1.11. The mathematical analysis assumes that the decision-maker is risk-neutral, because it assumes that the cost of the fine is the expected monetary value of that fine. The actual set of incentives is much more complex, but this is probably an adequate approximation for a commercial fisher, who might weigh up a small breach of the regulations in purely monetary terms. The model also assumes that the actual fine and the probability of capture have equal weight in calculating the expected fine, implying that the policy-maker can increase the expected fine in two equally good ways – increase the probability of capture or increase the fine. As increasing the probability of capture is expensive, the strategy of lobbying for increased penalties has been a common reaction of wildlife authorities to unsustainable poaching (Leader-Williams & Milner-Gulland 1993). However, the socio-economic studies discussed above suggest that the best strategy to achieve effective law enforcement is to increase the perceived probability of detection (Box 3.3). This whole discussion is made more complex by the involvement of several authorities, with different priorities and budgetary arrangements. Crime-reduction initiatives taken by law enforcement officials may not be supported by the judiciary in sentencing. For example, in Zambia, concern about the loss of elephants and rhinos due to ivory and horn trafficking, led the government to introduce mandatory 5–15 year prison sentences for elephant and rhino poachers in 1982. After 1982, magistrates did tend to deliver more prison sentences to elephant and rhino offenders, but not all of them received prison sentences. Those that did receive prison sentences received only a few months. The maximum length given over the first 3 years of the new law was 36 months. The legislation that was required to increase the penalties was slow and difficult to enact, meeting much opposition. Once in place, it was widely ignored by the magistrates, and has failed to curb poaching. The rhino population of the Luangwa Valley declined rapidly to near-extinction over the same period as the new legislation was coming into force (Leader-Williams *et al.* 1990).

3.2 Natural resources as economic goods

3.2.1 Externalities

In section 1.6, the market equilibrium for normal economic goods was described as the level of production at which the total utility obtained from the good is maximised; this is called the 'socially efficient' level of production. However, the open-access equilibrium in natural resource harvesting involves both economic and biological over-harvesting, and utility is not maximised. What is it that makes people over-harvest, and what is special about natural resources as economic goods that makes their market equilibrium socially inefficient? A socially efficient market is one in which the supply curve represents accurately all the costs involved in producing the good, and the demand curve all the benefits from the good. If the supply or demand curves do not represent all the costs and benefits involved in the market, then the point at which they cross is not the socially efficient production level (Fig. 3.1). This is called *market failure*. The costs and benefits that are not represented in the supply and demand from the African savannahs and calling the result a 'baseline' (Jackson, 1997). People are becoming more aware of the issue of *shifting baselines*, in which we tend to assume that what we observe now is the norm. As successive generations do this, the norm tends to shift, often towards lower quality as ecosystems deteriorate (Pauly 1995; Sheppard 1995).

4.2.1 Population data

Cooke (1995) highlights direct estimates of population size as vital for successful management. However, direct population estimates are often hard to obtain, particularly for forest or marine species. It is often easier to use estimates of *relative abundance*, which give trends in population size over time, but not actual population sizes. These are unsatisfactory, as they cannot be used to calculate offtake levels in advance. However, they can be used as tools to monitor broad trends in population size (Box 4.1). Freehling and Marks (see Chapter 10) use data from hunters to estimate trends in relative abundances for large mammal species in Zambia over 30 years, while Gunn (see Chapter 13) uses aerial surveys to track annual trends in abundance of caribou and muskox.

The accuracy of a population survey depends on the technique used, and the conditions under which it is undertaken. For example, elephants in small national parks in savannah ecosystems can be relatively precisely counted using direct aerial surveys. However, the elephants of the West and Central African forests can only be counted using indirect methods, principally dung counts (Barnes 1989). Thus, the estimate of the total number of elephants in Africa includes relatively precise estimates for eastern and southern Africa, and very imprecise estimates for Central Africa, where up to 38% of the continent's elephants may live (Fig. 4.2; Said *et al.* 1995). Some of this variation also depends on the effort and money expended on surveys. If survey techniques cannot provide an accurate population estimate, this needs to be taken into account in the allowable offtake if the resource is to be conserved effectively, for example, by making offtake levels inversely dependent on the accuracy of population surveys.

Cooke (1995) emphasises that it is more important to improve *survey methodology* whenever possible than to try to keep surveys comparable. Keeping surveys comparable has the attraction of allowing relative trends in abundance to be monitored over time, but this is outweighed by the danger of persistent biases. Changes in survey methodology can, however, produce highly misleading apparent changes in abundance, so it is important to resist the temptation to maximise the number of data points by comparing old estimates with those obtained under new methods. For example, much has been made of the 94% decline in black rhino numbers from 65 000 in 1970 to 3800 in 1987. Yet the estimates of rhino numbers, upon which this massive decline is based, are dubious in quality. They could all be under-estimates (Western 1989b), or the first figure could be up to 100% over-estimated (N. Leader-Williams, pers. comm.) although this still gives a decline of 89% over the period. The opposite

Box 4.1 Using relative abundance data from game scouts

Fig. B4.1a Black rhino and calf, Tanzania. (Photo by Dave Currey/EIA.)

Game scouts can be very useful sources of data on relative abundances, for species like black rhinos, which are very hard to count from the air. As they carry out routine patrols, they record the number of rhinos and elephants (and other game species) they encounter, as well as recording information on the number of scouts in the group, the route taken and the date. In the Luangwa Valley, Zambia, data from game scouts were available both for the period 1947–69 and for 1979–85. When confounding factors such as time of year, number of scouts in the group and patrol length were factored out, the data gave estimates of trends in rhino and elephant abundances (Fig. B4.1b).

These data suggest that there was no clear trend in rhino density over the period 1947–69. However, there was a catastrophic decline over the period 1979–85, caused by heavy poaching. The elephant data show a slower decline between 1979 and 1985, and also a rise in elephant numbers from 1947 to 1969, due to improved protection after setting up the national park. The recent rhino trend was confirmed by comparison with data on changes in actual rhino population sizes, collected in certain small and well-monitored areas of the Luangwa Valley. The two methods gave similar results. For elephants, aerial population surveys also tallied with the game scout estimates. The advantage of the game scout method is that the data are routinely collected anyway in the course of their duties, so that there is no extra cost involved in data collection, and large amounts of data are generated, with consistent monitoring over a long period (Leader-Williams *et al.* 1990).

continued

Box 4.1 *Continued*

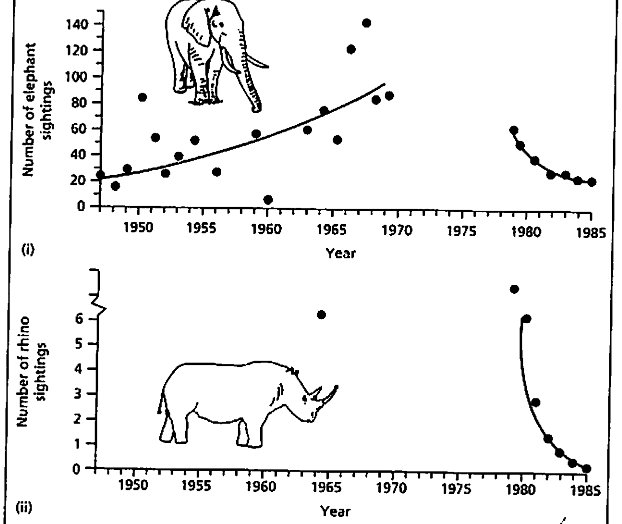

Fig. B4.1b Trends in elephant and black rhino abundances, 1947–69 and 1979–85 (from Leader-Williams *et al.* 1990). The trends have been standardised to numbers of sightings made by a four-person group, patrolling for 7 days in January, using an amalgamation of the data for the North and South Luangwa National Parks. (i) Elephant sightings. (ii) Rhino sightings (only one datapoint is given for 1947–69, the mean for the 23 years, as there was no significant trend in sightings over time).

effect, of an apparently large increase in numbers as survey methods improve, is also common (see Box 4.2).

4.2.2 Harvest and trade data

Direct data on the number of individuals killed, or data from the trade in their products, can be quite extensive for commercially valuable species, particularly if their products are exported. For example, good data on the trade in ivory from Africa stretch back to 1814, and there are patchy data back to the 16th century (Parker 1979). Often, trade data are much more easily available than population data, so it is important to know how to use them to infer trends in population status. For example, the number of lynx and snowshoe hare furs received by the Hudson Bay Fur Company over the

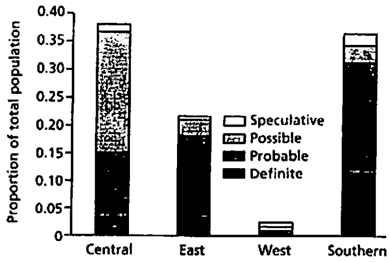

Fig. 4.2 Estimates of the population size of the African elephant in 1995 (Said *et al.* 1995), divided by region and quality of the data. Although Central Africa holds up to 38% of Africa's elephants, only 3% of Central Africa's population estimates are categorised as definite, compared to 75% of Southern Africa's estimates.

period 1840–1935 show such clear coupled oscillations that the data are used in ecology texts to demonstrate the dynamics of a predator–prey system (Fig. 4.3). If data on numbers killed are used as a proxy for the unexploited dynamics of a population in this way, the hunters must be taking a negligible proportion of the population, so that the hunting itself is not contributing to the population dynamics at all. Even using the data as an index of relative abundance requires that the hunting effort has not changed at all over the period, so that yields are directly related to population size. This is unlikely to be true in the case of the lynx and

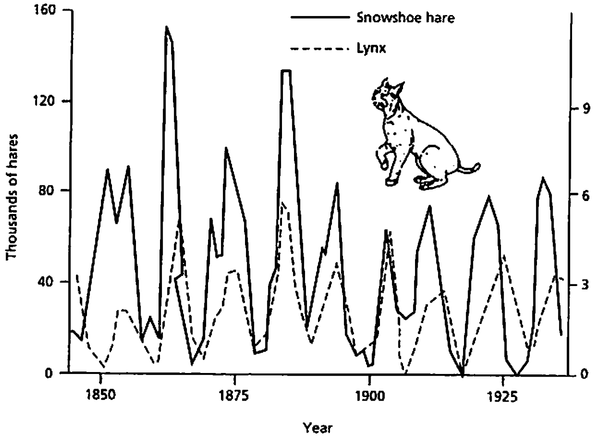

Fig. 4.3 The coupled oscillations of the lynx and snowshoe hare populations in Canada over the period 1840–1935. Data were collected from the number of pelts of each species taken to the Hudson Bay Fur Company each year. (From Begon *et al.* 1996a.)

growth. There are, however, caveats about using these data:

- Official data sources may be prolific, but that doesn't mean they are of good quality. Some government statistics are not worth the paper they are written on.
- The data are usually heavily aggregated. If local incomes from hunting and agriculture in a remote area are to be compared, for example, there is little point in using aggregated statistics – locally-based income calculations are more relevant. Often prices for produce vary strongly between local, national and international markets. The appropriate level must be chosen to represent the incentives faced by the people who actually decide harvesting rates. For example, if the decision-makers are middlemen based in the town, then national data can be used for calculating opportunity costs, but if local people are the ones who decide the amount of resource use, national data will be less useful.
- Time series of incomes, prices and discount rates can be very useful for relating changes in harvesting rate to changes in social conditions. However, constructing an econometric model of the market for a good is technically difficult (Maddala 1989). It is necessary to convert time series of prices or incomes into *real* values rather than using the actual values experienced at the time. This involves dividing the data by the consumer price index or the GNP deflator to remove inflationary trends. Inflationary trends are misleading, as they affect the whole economy. For example, the actual price of rhino horn in Japan was relatively stable from 1951 to 1970. It started to rise slowly in 1970, then rose dramatically from 1978. Taking real prices still shows a dramatic price rise over the period 1978–80, but in the context of a much more volatile previous price, and no steady rise from 1970 (Fig. 4.5). These real prices can then be related to the quantity of horn entering Japan, together with other economic

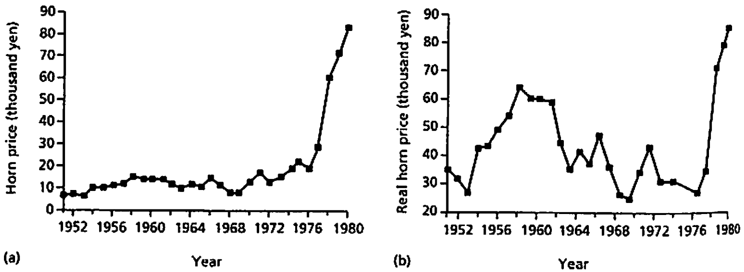

Fig. 4.5 (a) Actual rhino horn prices in Japan, 1951–80. (Data from Martin 1983.) These are the prices paid by consumers at the time. (b) Real rhino horn prices in Japan, 1951–80. (Consumer price index from IMF, 1981–88.) These prices are comparable over time, because inflation has been taken into account.

variables, in order to determine what drives demand for rhino horn. In this case, price did not significantly affect demand for rhino horn; GNP and changes in GNP were the main determinants of demand (Milner-Gulland 1993).

4.2.4 Ecosystem-level data

Ecosystems as entities are now receiving more attention from conservationists, who have traditionally been concerned with saving individual species, rather than protecting whole ecosystems and the processes within them.

The type of ecosystem-level data that is used for assessing sustainability depends chiefly on what is to be conserved. If a species is to be used sustainably, then data will be needed on the amount and quality of the habitat suitable for that species. If a whole ecosystem is to be used sustainably, or if conservation of an ecosystem is to be promoted by the use of a species from that ecosystem, then some measure of ecosystem health is needed.

For single species, the quantity of suitable habitat available may be relatively easily measured. The new IUCN criteria for *categories of threat* are used to classify species according to their danger of extinction (IUCN 1994). These new criteria explicitly recognise the size of the range area and habitat quality as important determinants of the threat status of a species. If a species is concentrated in very few areas, fragmented into many small areas, or if its habitat is declining in size or quality, it may qualify for threatened status. Habitat requirements are taxon-specific, so that large-bodied predators require large areas, while other species can survive indefinitely in very small areas (cave-dwelling endemics, for example). Calculations of the area requirements of different species can be done using the species richness of habitat remnants from the last ice age. They suggest that very few reserves are large enough to ensure that the populations of large carnivores within them can persist in isolation for 100 years, and none ensure persistence for 1000 years (Belovsky 1987). Although an adequate amount of suitable habitat is necessary for the conservation of a species, it is not sufficient, particularly if the species is exploited. In this case, there is no substitute for estimating actual population size to determine how fully occupied the habitat is. It is also important to be sure that the species is not intermittently reliant on particular habitat types that might be under threat. For example, the Soviet Virgin Lands project ploughed up most of the northern steppe of Kazakhstan in the 1950s. This appeared to make little difference to the saiga antelope population, but the ploughed area had been an important refuge for the species in severe drought years. The effect of this project on the saiga will only be seen under these extreme climatic conditions.