7 Conservation and rarity

Suddenly, as rare things will, it vanished.

R. Browning (1855)

. . . there is unfortunately no precedent for 5 billion human beings suddenly sharing an enlightened vision of the future.

N.R. Flesness (1992)

There are no hopeless cases, only people without hope and expensive cases.

M.E. Soulé (1987)

Considerations of rarity lead almost ineluctably to the topic of conservation. Indeed, it seems a popular belief that the two issues are inseparable. Previous chapters should have established beyond any doubt that this is not so. There are many questions about rarity which are of interest and yet have little directly to do with conservation. Nonetheless, it would be wrong to ignore this, the most important of the applied dimensions to the study of rarity.

The principal justification for a strong link between rarity and conservation is the idea that rare species have a greater likelihood of extinction than do others (the terms rare, threatened and endangered are often used almost interchangeably; Table 1.7 provides their IUCN definitions). The significance of this observation to some degree rests upon what are regarded as the ultimate objectives of conservation. These may be varied. Examples include the preservation of individual species, and the maintenance of vulnerable environments, of representative examples of different ecosystems, or of those processes which are essential to the existence of humankind. While all might be argued to have a role to play, one or other has tended to take precedence during different periods in the history of the conservation movement. The development of an overall strategy in which each goal is given appropriate emphasis and in which conflicts between those who recognize different goals are minimized, remains one of the great challenges to this movement.

The conservation of rare species is tied foremost to the view that a central objective of conservation is the prevention or limitation of the extinction of species. It may equally be argued, of course, that goals other than the preservation of individual species necessitate this preservation. In some instances this will be true; in others it will not. The maintenance of ecosystem function, for example, may not necessitate the presence of many species. Because typically we do not understand the role played by the majority of species the preservation of them all can perhaps be justified on the precautionary principle. However, given our present knowledge of ecosystems, and the constraints on what can in practice be achieved, this seems likely to be at best a weak line of argument (Lawton, 1991).

For the purposes of this chapter, we shall by and large ignore the particular grounds upon which the prevention of extinction is deemed desirable. Rather, emphasis will be laid upon: how good an indication of the risk of extinction the designation of a species as rare provides; and the role of rarity in conservation. It should be noted that, as in the previous chapter, rarity will be used in the broad sense of a low abundance and/or a small range. This is different from the more constrained sense in which it is used in many compilations of the species whose survival is most threatened in an area (Chapter 1, and see below).

A central tenet of what follows will be that conservation necessitates prioritization. Whether of sites or of species, prioritization is plainly at odds with some ethical and moral standpoints, implying as it does that some sites and some species can be regarded as being of more value than others. It is shamelessly a pragmatic approach. We cannot hope to maintain all sites in their present condition, return them to some past state, or manage them in some other way which we feel to be optimal for the purposes of conservation. Likewise, we will not be able to prevent substantial reductions in the abundances or ranges, and ultimately the extinction of many, very probably a great many, species as a direct or indirect product of man's activities. There is insufficient time, insufficient funding and insufficient political will.

Prioritization, either of sites or of species, may be performed at a variety of spatial scales. Thus, for example, the managers of individual reserves, regional, national and international organizations, are all frequently concerned, at their own scales of interest, both with identifying those areas of prime conservation importance and those species which are most threatened. Priorities are apt to form a nested hierarchy in which sites and species recognized as important on a large spatial scale are likely to be regarded as also being important on a smaller scale, but not necessarily the converse. There are balances to be struck regarding the resources provided for conserving the priority areas and species recognized at different scales. While a species which is rare within a given district or county may be widespread and abundant internationally, its conservation within that area may be important to the local people and action to conserve it may well affect their commitment to wider conservation issues.

7.1 RARITY AND LIKELIHOOD OF EXTINCTION

Rarity, whether expressed in terms of abundance or range size, is undoubtedly a major determinant of a species' risk of extinction at the scale at which it was recognized as rare (Chapter 5). In this sense it provides a reasonable basis for identifying those species most in need of conservation at this scale. However, our ability to predict confidently the likelihood of a particular species becoming extinct is limited. This is because there remains a great deal of variation in this likelihood, which differences in abundance or range size cannot explain.

Table 7.1 Possible factors contributing to the extinction of local populations. (From Soulé, 1983.)

Rarity (low density)
Rarity (small, infrequent patches)
Limited dispersal ability
Inbreeding
Loss of heterozygosity
Founder effects
Hybridization
Successional loss of habitat
Environmental variation
Long-term environmental trends
Catastrophe
Extinction or reduction of mutualistic populations
Competition
Predation
Disease
Hunting and collecting
Habitat disturbance
Habitat destruction

This is not unexpected and a variety of other parameters are also likely to affect extinction probabilities (Table 7.1).

7.1.1 Species attributes

Even within a taxon, species differ in an array of traits which may alter their vulnerability to extinction. Those that have been postulated to do so include body size, habitat or diet specificity, longevity, dispersal ability and trophic level (Leck, 1979; Diamond, 1984b; Pimm *et al.*, 1988; Burbidge and McKenzie, 1989; Kattan, 1992; Laurance, 1991). However, the interrelationships of these traits, both with one another and with abundance and range size (Chapter 6) complicate interpretation of their individual importance. The example of body size in animals will suffice. Large-bodied species can have characteristics which render individuals less susceptible to vagaries in the environment than small species (Wasserman and Mitter, 1978 and references therein; Cawthorne and Marchant, 1980), and they also have abundances which are frequently, though not always, lower than those of small species (Chapter 6). The former may reduce the risk of extinction that large species face, while the latter may increase it. Indeed, there are studies which have failed to find an effect of body size on a species' risk of extinction, and studies which have reported positive or negative effects (Terborgh and Winter, 1980; Karr, 1982a; Diamond, 1984b; Pimm *et al.*, 1988; Soulé *et al.*, 1988; Burbidge and McKenzie, 1989; Gotelli and Graves, 1990; Maurer *et al.*, 1991; Kattan, 1992; Laurance, 1991; Tracy and George, 1992).

In addition to the very broad potential correlates of extinction probability, individual rare species may possess various characteristics which reduce their vulnerability to extinction below that which might have been predicted for organisms of their abundance or range size. Rabinowitz *et al.* (1989) demonstrate that sparse species of prairie grasses tend to have temporally less variable reproductive output than common species in the same habitat. This buffered output is achieved through growth and flowering during a season when rainfall is more predictable, and may compensate for one of the hazards of small population size – demographic stochasticity – and thus reduce the risk of local extinction. Such adaptations may variously be viewed as the results of selective pressure on individual organisms to enhance the survival probability of their own descendants, or as resulting from the differential survival of species which possess them (selective extinction).

7.1.2 Environmental attributes

As well as abundance, range size and other species characteristics, risks of extinction also depend on the attributes of the environment (Diamond, 1984a; Tracy and George, 1992). These might include temporal and spatial variation in habitat variables, and the frequency of catastrophes (infrequent but severe environmental perturbations, the probability of a population surviving through which is, at best, only weakly a function of its size). Again, the relationships between rarity, environmental variables and extinction probability need to be carefully dissected. Thus, the idea that species in tropical regions are more prone to extinction could be explained as a consequence of their adaptation to environments which, broadly speaking, are less temporally variable (Stevens, 1989) which makes them more vulnerable to severe perturbations when they do occur. However, it might equally be explained as a product of their tendency toward having, on average, smaller range sizes and lower densities.

The relative importance of species' characteristics and environmental attributes when determining the likelihood of extinction remains unclear. Indeed there has been little empirical exploration of the effects of environmental variables on extinction rates, beyond the effects of area and of isolation.

7.1.3 Population dynamics

Population dynamics are only defensible as a category separate from the previous two on the grounds of convenience, as they can be explained in terms of some combination of species' characteristics and environmental parameters. Some of the possible effects of a species' population dynamics on its likelihood of extinction have already been alluded to (Chapter 5).

The most obvious population dynamic clue to a species' risk of extinction is, of course, its temporal trajectory. Populations and range sizes in decline face inevitable extinction unless that trend can be altered. The absence of a decline does not, however, mean that a species is not at severe risk of extinction.

Concern has grown over a far more subtle population dynamic effect on probability of extinction. That is the distinction between sink and source populations (Pulliam, 1988). Local source populations in which reproduction exceeds mortality may sustain sink populations in which local reproduction fails to compensate for mortality. The sinks may, however, comprise a large proportion of the regional population (Pulliam, 1988; Howe *et al.*, 1991). Species whose regional populations are so structured will be at greater risk of extinction than will those in which a greater proportion of individuals occur in self-sustaining populations.

As noted earlier, the fact that rarity alone is not a sufficient predictor of the probability of extinction of a species is one of the reasons Munton (1987) provides for dissatisfaction over use of a rare category in some schemes by which species are classified as under differing degrees of threat (Chapter 1). A more acceptable approach is to categorize species under several different variables (discontinuous) which contribute to risk of extinction, and then to rank the various combinations of states to provide a sequence of conservation priorities. Indeed, as Munton (1987) acknowledges, this has been done in some schemes. Using such an approach necessitates decisions being made regarding the optimal choice of variables and the ranking of combinations of their values to ensure that the species most at risk receive greatest priority in conservation planning.

7.2 MORE LIMITATIONS OF RARITY

Although more refined methodologies are plainly desirable, information on the threat faced by many species is so poor that whether they are rare or not is the best indicator available of their need for active conservation efforts.

Unfortunately, for the majority of species, data are inadequate to achieve even a categorization as coarse as whether they are rare or not. In particular, this applies almost uniformly to invertebrate groups. The primary reason is the sheer magnitude of the task. The invertebrate fauna of Britain, which is widely acknowledged to be the best documented in the world, comprises some 29 000 known species, with several thousand more probably remaining to be found or recognized (Stubbs, 1982). Information on abundance and spatial occurrence suitable for making conservation decisions is available for a few thousand of the total at most. Obtaining such information for the greater proportion of species is an unrealistic objective (Disney, 1986). In order to maximize the conservation of wholesale biodiversity (a large part of overall biodiversity; Williams and Gaston, 1994) priorities will of necessity be based on the identification and conservation of vulnerable assemblages of species and not upon species by species' categorization schemes.

It should be emphasized that we have no idea what the composition might be of the assemblage of species distinguished across all taxa as being rare at the global scale. Nor do we know the composition of the assemblage of, say, the 10% of species which are most threatened with extinction at the present time. A number of taxa have claims to disproportionate representation in the rare category when compared with their total species' richness. It has, for example, been argued that plant species are more prone to persistence at very small global population sizes than are other higher taxa and that most insect species have very small geographic ranges. A useful way forward might be to generate estimates of the breadth of values for the geographic range sizes of different groups of species. A few such figures are already available. Thus, Solem (1984) predicts that the median geographic range size of all land snail species will be considerably less than 100 km, and probably less than 50 km. Bibby *et al.* (1992b) report that 2609 landbird species have geographic ranges of 50 000 km^2 or less (27% of all bird species). One suspects that further work of this kind might reveal that the globally rare species comprise a fascinating, and rather surprising, mixture of taxa.

The biases in lists of rare, threatened or endangered species should lead to some caution in their translation into a set of conservation priorities. This translation might additionally be modified by the levels of protection which species are already experiencing, or the ease with which protection can be undertaken. McIntyre (1992) stresses the need to recognize groups of species whose conservation requirements have been neglected or underestimated.

7.3 SITES AND SPECIES

If we accept that the conservation of rare species is, for whatever reason, a worthy goal, then how in practice can it be achieved? Although the division is probably more artificial than it at first seems, two different strategies can be recognized, one site or habitat oriented, the other oriented about individual species.

7.3.1 Site prioritization

The majority of species will be conserved not through direct management of their populations, but, more indirectly, through the preservation of the habitats or sites (defined broadly in this context to include areas of any size) in which they occur. A variety of criteria have been proposed by which the most important sites for conservation can be identified. These include diversity (in its various meanings), rarity, numbers of biological interactions (e.g. predatory, competitive), representativeness (how unique or typical sites are), naturalness, ecological fragility, area, degree of threat, scientific value, potential value, management potential, spatial position, replaceability, amenity value, recorded history, educational value, and ease of acquisition (for reviews see Margules and Usher, 1981; Spellerberg, 1981, 1992; Goldsmith, 1983, 1991b; Usher, 1986a). Different studies have used varying subsets of this list, although some criteria are commonly applied (see Margules and Usher, 1981; Usher, 1986a).

(a) Rarity as a criterion

The presence of rare species has been used as a criterion by which to prioritize areas in many studies (e.g. Gehlbach, 1975; Goldsmith, 1975, 1987; Wright, 1977; van der Ploeg and Vlijm, 1978; Fuller, 1980; Game and Peterken, 1984; Dony and Denholm, 1985; Nilsson, 1986; Slater *et al.*, 1987; Wheeler, 1988; Eyre and Rushton, 1989; Daniels *et al.*, 1991). Indeed, rarity ranks as one of the most frequently applied criteria. Primarily this doubtless reflects the importance placed on the conservation of rare species. It has also been suggested that rarity is one of the more readily quantified criteria (Goldsmith, 1983), however, this is only because the bulk of studies of prioritization have used data for vertebrate or plant taxa in temperate regions.

No general standardized methodologies have been arrived at by which rarity can be scored for the purposes of site prioritization. Rather, *ad hoc* methods tend to be developed dependent upon the abundance and/or range size data available for any particular study. Rarity scores can simply be based on the number of rare species occurring at a site, or calculated as some product of the levels of rarity achieved by each species at the site (discontinuous versus continuous measures). By and large the latter approach tends to be used, providing as it does both greater information content and a more refined basis for decision making.

While for the purposes of site prioritization rarity has been measured on the basis of both the range sizes and abundances of species, range sizes are most frequently used, as estimates of their magnitude are more often available (exceptions include the study of Fuller (1980) who had access to abundance data for British birds). If abundances are used, range sizes are usually used as well. A potentially important, but generally overlooked, consequence of primarily using the range sizes of species rather than species' abundances for prioritization is that comparatively little weight is given to species which occur widely at very low densities. The populations of such species may need to be conserved at many sites if they are to remain viable. It is notable that several of the families of landbirds found to have no species with ranges less than 50 000 km^2, and therefore not contributing to the scheme of priority areas determined by Bibby *et al.* (1992b), comprised large-bodied species (e.g. bustards, storks, cranes) which often occur at very low densities.

Site prioritization based, if only in part, on rarity, only makes sense if species are categorized as rare or otherwise at some higher spatial scale than that of the sites themselves. Species are thus typically categorized as rare or otherwise with respect to their spatial distribution or abundance across the geographic area within which all the sites occur. Categorizing species with respect to the individual site would be unhelpful because species which are rare with respect to the whole geographic area, and therefore most in need of conservation, may be abundant at one or more individual sites. Likewise, species which are rare with respect to individual sites may be abundant with respect to the whole geographic region.

Which higher spatial scale is chosen for defining rarity may, of course, affect where different component areas lie in the resultant sequence of priorities. One way of trying to account for this complication is to weight species on the basis of their rarity at more than one spatial scale (e.g. Jefferson and Usher, 1986;

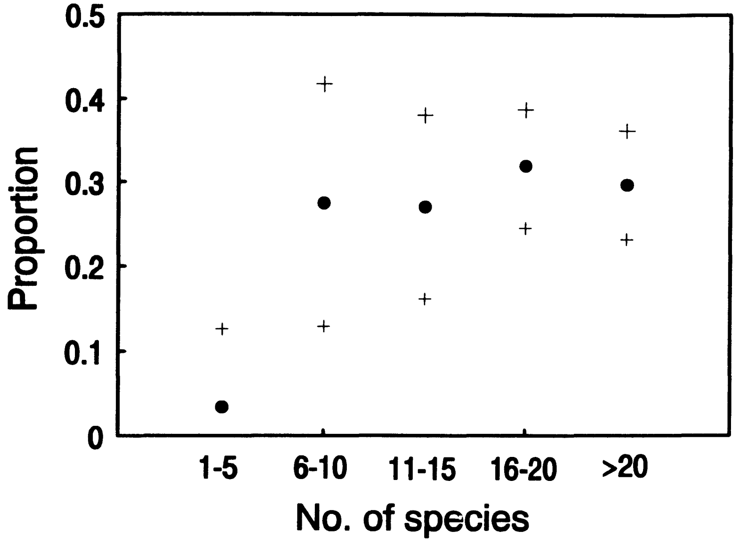

Figure 7.1 The proportion of species and subspecies which had restricted geographic ranges in butterfly assemblages of differing richness in the Moroccan Atlas mountains (restricted range species are those with at least one third of their range in North Africa, and restricted range sub-species are those with at least half of their range in North Africa). Dots are means, and crosses ± 1 SD. (Redrawn from Thomas and Mallorie, 1985b.)

Rapoport *et al.*, 1986; van der Ploeg, 1986; Daniels *et al.*, 1991), or to weight them according to the scale at which they are rare (e.g. Brooker and Welsh, 1982; Jenkins *et al.*, 1984). Thus, for example, in their study of the conservation value of ecological zones, habitat types and specific localities in a south Indian district, Daniels *et al.* (1991) first assigned conservation values to each of the bird species of the district. These values were based on seven variables, four of which related to the species' geographic ranges at different scales (over the entire world, over the Oriental region, over the Indian subcontinent and over the Malabar province).

It is commonly observed that, using a variety of definitions of rarity, the number of rare species at a site tends to be positively correlated with the overall species richness (Figure 7.1; Pearson, 1977; Järvinen, 1982; White *et al.*, 1984; Thomas and Mallorie, 1985b; C. Nilsson *et al.*, 1988; Wheeler, 1988; Dzwonko and Loster, 1989). It has also been found that the mean range size of species in an assemblage declines with the numbers of species present, which may amount to much the same thing (Figure 7.2; Rosenzweig, 1975; McCoy and Connor, 1980; Anderson and Koopman, 1981; Anderson, 1984a, b, 1985). In prioritization studies these observations translate into a tendency for high rarity scores to be associated with greater species' richness, either because rarity scores are simply the numbers of rare species or because they are correlated with these numbers.

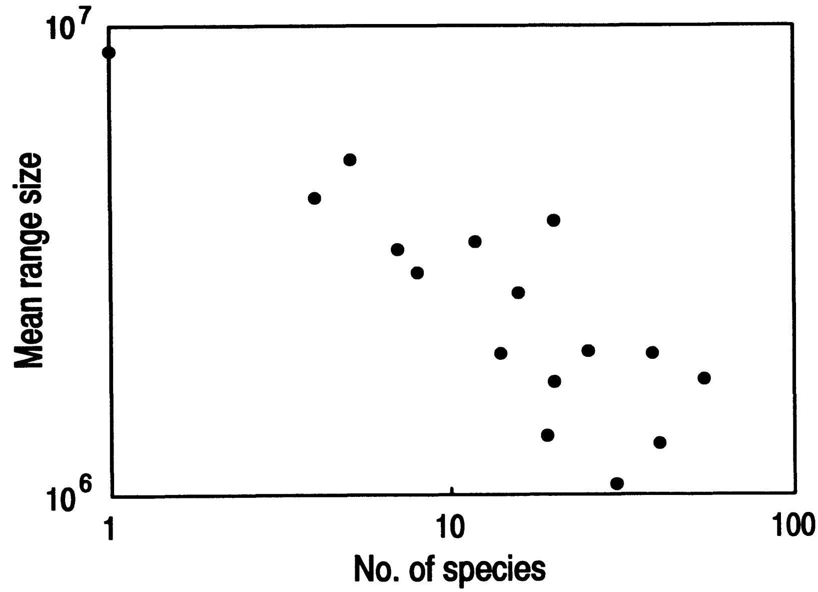

Figure 7.2 Relationship between the mean range size (km^2) of the species of reptiles occurring at different sample sites in North America and the number of species occurring at those sites. Some data points refer to more than one site. (Redrawn from Anderson, 1984b.)

Any tendency on the part of rare species to aggregate may be welcome, as it potentially reduces the numbers of sites that need to be protected in order to conserve them. Indeed, from this perspective the optimal scenario is perhaps that in which the ranges of species in an assemblage are nested such that species only occur in those places where the species with the next largest range also occur. In terms of the potential ease with which large numbers of species could be conserved it is encouraging to find that some 20% of all bird species are confined to just 2% of the earth's land area (Bibby *et al.*, 1992b). However, equally this emphasizes how essential it is to protect those areas.

As yet, our abilities to predict the numbers of rare species of a given taxon in an area are limited. Documented relationships between environmental characteristics (e.g. topography, habitat, climate) and the richness of rare species are increasingly being seen as a way round this problem, on the rationale that it is far easier to obtain data on the environmental conditions in an area than to document its fauna or flora adequately. Relationships between environmental characteristics and known patterns of occurrence have been explored in a number of studies (White *et al.*, 1984; Miller, 1986; Miller *et al.*, 1987, 1989; C. Nilsson *et al.*, 1988; White and Miller, 1988; Hill and Keddy, 1992). Hill and Keddy (1992), for example, developed predictive models relating the species' richness of rare plants to measured habitat variables for the shoreline vegetation of lakes in southwestern Nova Scotia. Multiple regression models using habitat variables accounted for 83% of the variability in species' richness of rare coastal plain species, compared with only 45% of that for the background flora. More studies of this kind are needed, as is some consideration of whether there are any generalizations to be made as to the combinations of variables which have the best ratio of predictive value to obtainability.

(b) Weighting different criteria

Alone, the rarity scores of sites will often provide an insufficient basis for prioritization. As noted earlier, rarity is one of many criteria upon which sites can be prioritized. Even if the sole intention were the preservation of the rare species themselves, this might most effectively be achieved at sites which do not rank highest on the rarity scoring, but on other, or a combination of other, variables. Paradoxically, as Goldsmith (1987) points out, if judged by rarity alone, the conservation value of a site could be increased by making its rarities even rarer rather than by reducing their vulnerability to extinction.

In most studies, a final ranking of sites is generated by combining the scores of different criteria to generate a single index. Typically no differential weighting is applied to the various scores, largely because there is no obvious way to do so. Indices can either be calculated once or iteratively, in the latter case on the assumption that, for example, at each step the site with highest scores has been conserved (e.g. Kirkpatrick, 1983). Iterative models are more efficient than simple scoring approaches, in that they can, for instance, more effectively ensure maximization of conservation criteria in the fewest or smallest areas (Margules *et al.*, 1988; Pressey and Nicholls, 1989a, b).

(c) Taxa

It has often been assumed, albeit tacitly, that the optimal ranking of sites for the conservation of one taxonomic group of species (usually plants) will also be optimal for other taxa occurring at those same sites. Such an assumption may equally often be false. Although not of itself a sufficient condition, this is implied by the observation that the patterns of species' richness of different taxa are often far from congruent, both at large (e.g. Schall and Pianka, 1978; Pianka and Schall, 1981; MacKinnon and MacKinnon, 1986b; Currie, 1991; Gentry, 1992) and at small spatial scales (Emberson, 1985; Usher, 1986b). More directly, Ryti (1992) has demonstrated that the use of different taxa as the basis for the selection of nature reserves can profoundly alter success at the inclusion of other taxa.

This is not to say that the richness of one taxon never provides information on the richness of another. There are ample examples of relationships between the numbers of insect species and the numbers of plant species in different areas (e.g. Abbott, 1974; Otte, 1976; Hockin, 1981; Reed, 1982; Itamies, 1983; S.G. Nilsson *et al.*, 1988; Brown and Opler, 1990). Even where such relationships exist independently of area effects, they need to be treated cautiously, in that one or other taxon may increase in richness at a rate that is disproportionate compared with the other. Thus, areas which differ markedly in the richness of one taxon may not differ so markedly in the richness of another.

There is, however, for most regions of the world little alternative to basing the prioritization of sites on one taxon or a few taxa. The extent to which this strategy serves to conserve species of other taxa will have a profound effect on how future generations view the success of present-day conservation efforts.

(d) Design, acquisition and dynamics

There are inadequacies in the existing reserve system. Reserves cover an insufficient proportion of the world's land surface (at present about 3–4%, and far less for marine habitats), are haphazard in distribution, tend to be located in areas of no economic value rather than in areas of high importance for conservation, and are often (usually?) too small (Spellerberg, 1991). If this situation is to be rationally improved in an optimal fashion, it will necessitate a closer marriage between the procedures by which sites are prioritized and many of the principles of good reserve design and management (see Spellerberg (1991) and Morris (1991) and references therein for entries into the literature on these topics).

Some aspects of these principles are included reasonably frequently among the criteria for prioritization studies (e.g. site area), but others are more seldom considered (e.g. site shape, location and connectivity; but see Bedward *et al.*, 1992). In particular there is a general need to include information on the probability that conserved areas will remain conserved and will not be seriously degraded and on other social and political dimensions (see Soulé, 1991). This would go some way to answering critics of the derivation of rules for prioritizing sites who argue that it ignores the practical reality that there is often no opportunity for their application.

Schemes of prioritization will also have to address two further, linked, issues. The first is a recognition of the need to move further towards a matrix approach to conservation, based not only on reserves, but also on non-reserve lands, often non-pristine lands. It is increasingly understood that a successful conservation strategy must include planning for the landscape as a whole. There are several reasons. Reserves themselves do not exist independently of the areas that surround them, reserve systems alone will never be adequate, and non-reserve lands frequently provide important areas of habitat. By way of an extreme example of the final point, comparison of the floras of seven English counties revealed that industrial sites are the sole or major habitat for between 9 and 31% of the species occurring in those counties (Kelcey, 1984).

The second issue that will need to be addressed is the fundamental flaw in a conservation strategy that focuses primarily upon a static system of isolated reserves. It ignores the fact that the geographic ranges of species shift in

Table 7.2 Means by which populations of rare species can be increased or maintained

Establishment of protected areas
Captive breeding
Supplemental feeding
Habitat manipulation
Reintroduction (from captive or wild populations) into areas where previously did occur
Introduction (from captive or wild populations) into areas where previously did not occur
Translocation between areas where already occur (e.g. to facilitate maintenance of genetic diversity)
Elimination or reduction of competitors, predators or parasites
Abolition of exploitation (e.g. hunting, collecting)
Manipulation of reproductive biology
Manipulation of behaviour (e.g. fencing to restrict dispersal)
Veterinary, sylvicultural and equivalent care of wild individuals

response to environmental change (Chapter 5; Huntley, 1991). At the least, it is necessary to have a network of interconnected sites. Such considerations are of particularly great importance in the light of the rapid changes in climate predicted in coming decades.

7.3.2 Focal species

The distinction between an approach to the conservation of rare species which is centred on habitats or sites, and one that is centred on particular species is blurred because focal (or 'flagship') species can only be preserved in the wild through adequate preservation of habitats. The latter inevitably leads to the preservation of non-focal species. The difference in the numbers of rare species which will be conserved effectively by the two approaches is liable to be case dependent, and a function of the degree to which general, good reserve design principles are practised.

This said, species-by-species conservation is in practice usually an exercise in crisis control (Guerrant, 1992). It is quite simply the only means by which a growing number of species can be prevented from becoming extinct. The classification of species according to the degree to which they are threatened with extinction provides a means of recognizing crises, or perhaps more realistically at the present time, the most serious crises.

As in considering a site-based approach to conservation, I have no intention of providing any detailed prescription of the process of conserving given species. The means by which populations of rare species can be managed are as diverse as the possible causes of their rarity (Tables 7.2 and 7.3). Rather, I have sought to identify some of the principal issues involved in species-by-species conservation of rare species:

(i) Ideally, the future survival of a particular rare species is achieved

Table 7.3 Suggested management actions to increase the likelihood of the survival of Hawaii's endangered birds. A, legal protection of natural habitats; B, elimination of exotics; C, physical restoration of habitats; D, intensive manipulation of birds; E, translocation of birds; F, captive propagation and release to the wild. (From Scott and Kepler, 1985.)

	A	*B*	*C*	*D*	*E*	*F*
Hawaiian Goose		+				
Hawaiian Duck	+					
Laysan Duck		+				
Hawaiian Hawk	+					
Common Moorhen	+					
American Coot	+					
Black-necked Stilt	+					
Hawaiian Crow	+					
Nihoa Millerbird					+	
Hawaiian Thrush		+				
Small Kauai Thrush		+				
Kauai Oo		+				
Laysan Finch					+	
Ou	+					
Palila	+					
Maui Parrotbill		+				
Common Amakihi		+				
Kauai Akialoa		+				
Nukupuu		+				
Akiapolaau	+					
Hawaii Creeper	+					
Molokai Creeper	+					
Oahu Creeper	+					
Akepa	+					
Crested Honeycreeper	+					
Poouli		+				

through recognition of the factors which limit its abundance and/or range size, followed by action to relieve those (or other) restrictions. The natural causes of rarity are multifarious and complex (Chapter 6), thus there are equally endless ways in which the future survival of a species can be reduced through human actions. In broad terms, of course, it is not necessary to look far to identify the major threats. The single most important threat is the ever changing pattern of land use; the seemingly remorseless destruction of natural habitats and their replacement with agricultural and urban developments, and the 'improvement' of much agricultural land (e.g. Tables 7.4 and 7.5). Land

Table 7.4 Causes and causal agents of the decline of threatened plant species in the former Federal Republic of Germany. Owing to multiple listing of species endangered by different factors the sum of species is greater than the total number of individual species. (From Sukopp and Trautmann, 1981.)

	Species
Causes (factors)	
Elimination of special habitats	210
Drainage	173
Abandonment of land use	172
Landfilling, grading	155
Alteration of land use	123
Strip mining, removal of top soil	112
Mechanical impacts (e.g. trampling, camping)	99
Herbicide application	89
Impacts of weeding, clearing, fire	81
Dredging of rivers and lakes	69
Collecting	67
Water eutrophication	56
Discontinuance of periodical soil disturbance	42
Water pollution	31
Urbanization of villages	20
Causal agents (land-use systems)	
Agriculture including land consolidation and improvement	397
Tourism and recreation	112
Mining of raw materials, quarrying	106
Urban – industrial utilization	99
Water management	92
Forestry and hunting	84
Disposal of refuse and waste water	67
Fish pond management	37
Military	32
Traffic and transportation	19
Science	7

use is the major factor determining commonness and rarity in many faunas and floras, as illustrated by Hodgson's (1986b, 1991) work on the British flora. Many, though perhaps not all, of the large scale declines of whole groups of species can be viewed as the results of habitat alteration (Holmes and Sherry, 1988; Terborgh 1989; van Swaay, 1990; Hill and Hagan, 1991; Desender and Turin, 1989).

(ii) While general threats to rare species may often, though not always, be

Table 7.5 The numbers of taxa under different general kinds of threat in the freshwater fish faunas of western and eastern North America, north of Mexico. (From Deacon, 1979.)

	Western		*Eastern*	
	N	*(%)*	*N*	*(%)*
Habitat modification	109	(97.3)	90	(100)
Overexploitation	0	(0)	6	(6.7)
Parasitism and disease	5	(4.4)	0	(0)
Biotic interactions	60	(54)	8	(8.9)
Restricted range	24	(21)	6	(6.7)

identifiable, the precise causal links whereby they bring about reductions in species' abundances or range sizes may be more difficult to recognize. There are a number of considerations:

- Ideally, the particular causes of the rarity of a given species are determined through detailed study of its biology. However, such studies are demanding in both time and resources, and are in most cases unrealistic undertakings. Much important knowledge can be gained through more cursory comparisons of some basic ecological and life history parameters (Hodgson, 1991), but even such data as these are often hard to come by.
- The causes of the rarity of a given species may not operate all of the time, but rather be expressed in brief 'crunch' periods. Detection of such effects may necessitate time series data.
- Determination of the causes of rarity of threatened species is, almost invariably, based on observation rather than experiment. This carries some inherent dangers. In particular, it is liable to lead to reliance on the presumed basis of documented correlative analyses. An example is the presumption that observed habitat and resource usage reflect the best available options (that is they are optimal). Gray and Craig (1991) make the point that such a conclusion should not be reached automatically for any species, let alone one facing extinction. The species may be able to do much better in habitats and with diets outside its pattern of observed usage. Indeed, in the past its ecological requirements may have looked somewhat different and its true flexibility may be greater than even past usage might imply.

  This observation serves to emphasize the potential applied importance of an issue considered earlier from a 'pure' perspective, namely the interactions between the realized and fundamental niche spaces of species and their realized abundances and ranges sizes (Chapter 6).
- Species can be too rare for the cause of their rarity to be determined. This was true of more than a third of the species in Hubbell and Foster's (1986) work on the woody plants of their study plot on Barro Colorado island (Table 7.6).

Table 7.6 Some causes of rarity among woody plant species with fewer than 50 individuals in a 50 ha plot on Barro Colorado Island. (From Hubbell and Foster, 1986.)

No. of species (%)		*Apparent cause of rarity*
9	(8.1)	Most plants too small for inclusion in census
12	(10.8)	Habitat restriction
42	(37.8)	Common in second-growth forest
5	(4.6)	Other (hybrid, selectively cut)
43	(38.7)	Too rare to determine

It is a particular problem when working on species which occur at very low densities in complex habitats.

(iii) The price of failing to diagnose the detailed causes of species' rarity correctly can be high. Ignorance of the subtle habitat requirements of some British butterflies meant that the loss of many local populations could not be prevented until remedial action was taken (J.A. Thomas, 1991). Green and Hirons (1991) identify initial misdiagnosis of the causes of a species' plight as a cause of the often long (10 years or more) delay between the start of research on and the recovery of the populations of individual endangered species of birds.

Lande (1988) gives examples of two management plans, for the northern spotted owl (*Strix occidentalis caurina*) and the red-cockaded woodpecker (*Picoides borealis*), which were based primarily on population genetics, ignoring basic demographic factors, and as a result threatened the existence of the species they were designed to protect.

(iv) There have been attempts to provide broad guidelines regarding the most appropriate management strategies for rare species, on the basis of the general causes of their rarity (e.g. they are relict species, regulated by biological factors, or isolates at the edge of their range; Main, 1984). There seems little prospect of such schemes proving of much practical value.

(v) Harper (1981) relates that a straw poll of a lecture audience revealed that the majority did not wish to see rare species made more common. As he states, 'This would seem to indicate that by some remarkable chance the flora of 1980 is just right and that the conservationists' task is to maintain this condition! ' Likewise, Kelcey (1984) notes the 'overwhelming desire to maintain a rare species as a rare species'. Attempting to maintain many rare species at present abundances is not, however, likely to be an efficient means of ensuring their continued survival. It will necessitate frequent intervention to prevent extinction, while not permitting the enhancement of their populations which would reduce this frequency. These comments highlight a broad question. At what point in a conservation programme is the abundance or range size of a species considered sufficient for the programme to be regarded as successful and terminated?

(vi) Although seldom referred to, measures directed at the conservation of some species may threaten others. For example, improvements to the water supply for the Owens River pupfish (*Cyprinodon radiosus*) resulted in the near loss of one of two populations of a snail endemic to the Owens Valley in California (J.M. Scott *et al.*, 1987). Likewise, management for large mammals in the Addo Elephant National Park (eastern Cape province, South Africa) has reduced resource availability for the large, flightless, dung-feeding scarab (*Circellium bacchus*) which is restricted to the park and surrounding farms (Scholtz and Chown, 1993).

The potential for such clashes is greatest when an area is being managed for the benefit of a particular focal species, rather than when the reasons for management are more broadly based. They are also most likely to occur when the taxa concerned operate on very different spatial scales (e.g. they are of very different body size; Scholtz and Chown, 1993). This latter observation suggests that as more attention is paid to the conservation of invertebrates, and particularly insects, the incidence of documented cases of such problems is liable to increase.

Improved information on the distribution and vulnerability of rare species will serve to reduce the occasions on which the continued survival of one species is accidentally threatened through actions to preserve another. However, ultimately hard decisions may have to be made as to which species have priority. The emphasis presently laid upon the desirability of creating corridors by which habitat patches can be linked is one instance where such conflicts are likely to be acute. What is a corridor to one species is apt to be a barrier for another.

7.4 CONCLUDING REMARKS

History has already demonstrated humankind's inability (in practice rather than principle) to coexist with all the other species extant at any given time. As a direct result of human activities we have witnessed the loss of numerous species and suspect the loss of many more. It seems almost inevitable that unless conflicts between the resource demands of people and wildlife are not reduced drastically, mass extinction will result. Humans have, of necessity, to impact upon the world around them. Nonetheless, choices exist as to the form that impact takes. An understanding of rarity provides a tool whereby those areas and species likely to be the most important indicators of the success of those choices in permitting global coexistence of the maximal number of species can be judged.