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THE VALUE OF BIODIVERSITY: WHERE ECOLOGY AND ECONOMY BLEND

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Abstract

As problems of environmental change become more evident, we increasingly realize how much we depend upon wildlife for a wide range of so-called ecosystem services. These services, which include soil protection, pest control and the supply of clean water, are to a significant extent provided by natural and semi-natural ecosystems which in the past were thought to have little or no economic significance. This recognition has important implications for conservation. The emerging discipline of ecological economics provides methods for assessing the economic value of wildlife. While it is idle to pretend that the application of such methods will solve the biodiversity crisis, economic analysis can be useful in strengthening the case for conservation. Such analysis can demonstrate the potentially high economic value of wildlife, and reveal more clearly the economic and social pressures which threaten it. It is argued that while nature reserves and other protected areas will always be important, we must shift our attention increasingly to the preservation of biological diversity within the major forms of land-use. High priority must be given to finding ways of restoring biological diversity and enhancing ecosystem function in those areas which have already been seriously damaged. In these tasks ecological economics has an important role to play. © 1998 Published by Elsevier Science Ltd. All rights reserved

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THE FIRE-BRIGADE PERIOD—THE FIRST 100 YEARS OF CONSERVATION

Anyone who becomes involved in conservation work soon discovers that it is a truly multidisciplinary activity. Whatever their formal training, there is likely to be some aspect of their work—for example, monitoring, management, dealing with planning authorities or public relations—for which they have no adequate background. This article (written, it should be said, by two biologists) concerns the growing importance of economics in conservation policy. In it we seek to develop two arguments. The first is that the role and importance of conservation are changing dramatically. These changes have come about through the rapid increase in environmental problems, and the recognition that biological diversity is an essential resource for human survival. The second argument is that conservation, which has hitherto been an interest of the minority, must increasingly be drawn into the mainstream of social and economic activity. In this new context, economic analysis of the full costs and benefits of preserving wildlife becomes an important tool for effective conservation.

Although the beginnings of biological conservation can be traced back into the last century or even further (e.g. Regenstein, 1991; Evans, 1992; Beezley, 1993), the activity as we know it today is really a product of the last hundred years. We characterize this phase of conservation, with its priorities on inventory and rescue, as the 'fire-brigade period'. During this period, conservation has been to a large extent a specialist activity, promoted and undertaken by enthusiastic amateurs, academics, and a relatively small number of trained professionals. The motivations of conservationists have been partly the scientific interest of wildlife and natural habitats, and partly more personal values such as an appreciation of the beauty of living things. Thus, conservation has developed as a specialist and to some extent elitist activity, dominated by scientists and amateur naturalists.

Priorities for conservation during the fire-brigade phase have often been determined by a museum type of approach, in which the aim has been to select for protection representative examples of the range of natural habitats. Such an approach can be seen, for example, in the criteria for selection of Sites of Special Scientific Interest in Great Britain (Ratcliffe, 1977; Evans, 1992).

Apart from the growing use of protected areas for tourism, conservation has had rather little influence upon people's aspirations and life styles, and little impact upon economic activity. Indeed, one of the major problems for biological conservation is that it carries with it the image of a sectional interest, whose needs can be met within the confines of protected areas. The attitude certainly exists amongst politicians that, while a government has a responsibility to ensure that some areas are protected for wildlife (at most, a few per cent of the total land area), the needs of conservation cannot be allowed to constrain economic activity outside the areas so designated. An inevitable consequence of such an attitude is that protected areas, although formerly part of a more extensive area of contiguous habitat, often become ecological islands which are too small or too isolated to support all of the species that were originally present.

CONSERVATION AND THE ENVIRONMENTAL CRISIS

We believe that the fire-brigade phase of conservation is coming to an end, at least in the developed world. The achievements have been that we now have a substantial, though far from complete, knowledge of the abundance and distribution of threatened species and habitats, and the best natural areas have some form of legal protection. However, it is abundantly clear that these measures are quite inadequate to prevent or even stem an accelerating loss of biological diversity. As early as 1978, Fitter and Scott (1978) recognised that the rescue process was inadequate. 'Today habitat destruction is proceeding at such a pace that the creation of reserves, however effective twenty or thirty years ago, is now plainly inadequate. Most national parks and nature reserves are much too small ... Conservationists simply must find some ways of conserving a substantial proportion of the worlds remaining unspoilt ecosystems without waiting to see how these areas are going to be named, administered or used.' More recent analyses of the threat to species and habitats only serve to confirm this opinion. For example, the Global Biodiversity Assessment (Heywood and Watson, 1995) presents data to suggest that the rates of extinction of vertebrates and vascular plants are now 50 to 100 times the expected background, values which many other sources would regard as underestimates. In rain forest the absolute rate of species loss is estimated at about 1000 to 10 000 times that before human intervention (see Wilson, 1988).

However, the end of the fire-brigade phase is not simply a consequence of the growing rate of species and habitat loss. A powerful new argument for protecting biodiversity has emerged in the past 10 years: we need it for our survival. This realisation has grown gradually as a result of the increasing scale of environmental problems we face, such as acidification (Brunnée, 1988), eutrophication of waterways (e.g. Rechcigl *et al.*, 1992; Atkins *et al.*, 1993), extreme flooding events (e.g. Platt, 1994), destruction of ozone layer (Brunnée, 1988) and climatic change (Smith and Tirpak, 1989). These developments have focused attention upon the impact that modern economic activity has upon the environment, and also upon the role of the biota in controlling environmental conditions. We all depend for our survival upon processes such as biological productivity, nutrient cycling, and water cycling which provide clean air and water, maintain the fertility of the soil, and help to regulate the climate. These processes, which are now called ecosystem services (Ehrlich, 1995; Ehrlich and Ehrlich, 1992; Mooney *et al.*, 1996), are to a significant extent provided by natural and semi-natural ecosystems such as wetlands which in the past were not thought to have economic significance.

A good example of the importance of ecosystem services is provided by agriculture. In the past 40 years, agriculture has been seen increasingly as a technical process, in which outputs are a function of inputs such as pesticides and fertilizers. Ecological processes which help to maintain fertility or control pests and diseases have been considered much less important in maintaining production. However, we are increasingly seeing the limitations of technological solutions. Forty years of intensive development of pesticides have produced growing problems due to the evolution of pesticide resistance, and the destruction of natural enemies which formerly helped to reduce pest species (Altieri, 1991, 1994). Biological diversity in agro-ecosystems has declined dramatically, and the loss of diversity is continuing. For example, populations of many species of farmland birds in Europe have decreased greatly in the past 20 years (Marchant *et al.*, 1990; Gates *et al.*, 1994). Despite increasing use of fertilizers, the productive capacity of some soils is also declining (e.g. Parr and Hornick, 1992). A new discipline called agro-ecology is emerging which recognises the need to develop agricultural systems which depend upon ecological processes to maintain production and control pests and diseases. Inevitably, this means a greater dependence upon biological diversity.

VALUING BIODIVERSITY

An important consequence of the environmental crisis is that biodiversity is increasingly recognised as an essential yet diminishing resource. Since, in definition economics concerns the efficient use of scarce resources, there is an obvious role for economic analysis. Indeed, the formulation of the concept of ecosystem services was a deliberate attempt to draw ecological processes into the domain of economics. As long as the supply of these services was more than ample, there was no need to consider them in economic terms, and for this reason economic activity often caused them to be significantly degraded (Freedman, 1995). An important step in sustaining these conventionally non-valuated resources is, therefore, to define them as goods and services which can be quantified in economic terms. In recent years, economists have made important progress in defining the kinds of benefits that biological diversity provides, and in developing methods for assessing their value.

There is now a well established classification of major categories of value from biodiversity (Groombridge, 1992; Filion and Adamowicz, 1994; Pearce and Moran, 1994; Young, 1995; Fig. 1). The most obvious value is from *direct extractive uses*, such as the production of timber or the collection of plants and animals for food. There may also be *direct non-extractive uses* of biodiversity, such as their importance for recreation or tourism. *Indirect uses* of biodiversity include the role of organisms in providing ecosystem services such as flood control, pest control or protection against erosion. There are also *optional uses* which concern the possible use of a resource at some point in the future. These optional uses include, for example, the potential, though as yet unknown, importance of plants as a source of chemical substances or the potential importance of natural areas for providing ecosystem services, even though these services are as yet unimportant. Non-use values are rather more difficult to define and estimate, but are commonly divided between a *bequest value* and an *existence* or *passive use value*. The former measures the benefit accruing to an individual from the knowledge that others might benefit from a resource in the future. The latter are those motivated by sympathy for the natural environment and the mere existence of particular species (Pearce and Moran, 1994).

Of these benefits, only the first two can easily be quantified in financial terms, though even this is rarely done. An example is a recently published analysis of the economic importance of wildlife in Canada, based upon the direct benefits such as hunting, fishing and tourism, as well as the ripple effects that such activity has upon the Canadian economy (Filion *et al.*, 1994). Even this limited analysis suggested that in 1991 wildlife was worth seven billion dollars to the Canadian gross domestic product and sustained over 126 000 jobs. The other categories of economic value present greater difficulties of assessment, though a sizeable literature now exists concerning the valuation of biological resources (Van Ierland, 1993; Bromley, 1995; Munasinghe, 1995; Perrings, 1995; Willis and Corkindale, 1995). Methods for estimating the value of ecosystem services often rely upon estimating the replacement costs of those services. For example, the alternative to coastal defence through sand dunes or salt marshes might be the construction of a sea wall. The estimated cost of such a structure provides a surrogate value for the ecosystem. There are also a variety of methods based upon careful questionnaires in which people are asked what monetary value they place upon a resource. The questions thus address people's willingness to pay for biological diversity, for example through increased taxation. Such 'Contingent Valuation' methods can be used to estimate not only hypothetical use values (for example, how much will people pay to be able to swim in clean rather than polluted water), but also non-use values.

These categories of economic value are important for conservation because they force us to consider all of the benefits which we obtain from wildlife, and not simply those which are tradeable. As an illustration of the diversity of benefits from a natural habitat, Table 1 presents a list of the benefits to be derived from river corridor vegetation, all of which (except perhaps landscape quality) are potentially quantifiable (Petts, 1990). Indeed, when the full value of a natural ecosystem is quantified, the results can be quite surprising, especially in the case of wetlands (Costanza *et al.*, 1989). A review of wetlands in Canada assigned a value of $50 000 per

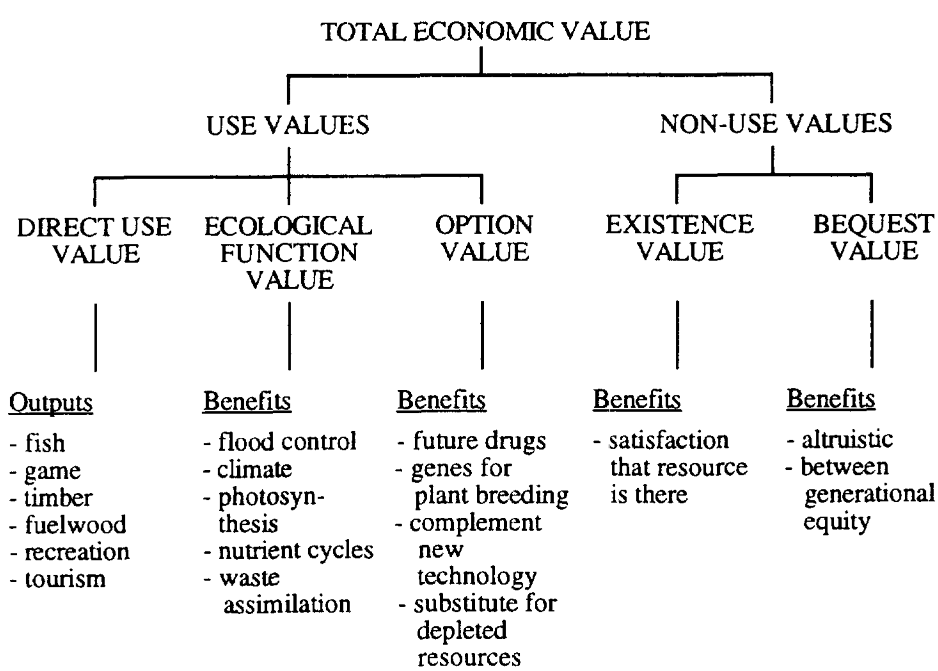

Fig. 1. The nature of total economic value (Young, 1992; after Barbier, 1991).

Table 1. Benefits from river corridor vegetation (after Petts, 1990)

1 Regulation of flow by wetland vegetation
2 Regulation of water quality: swamps and riparian wood are efficient sinks for N and P
3 Regulation of water temperature by riparian woodland
4 Input of organic food for the aquatic community
5 Stabilising of channels and bank
6 Creation of habitats for aquatic wildlife: natural rivers are more diverse
7 Enhanced fish production
8 Production of timber products from riparian forest
9 Creation of habitats for terrestrial wildlife
10 Enhanced landscape quality

hectare to their functions in water purification and as pollution sinks, and \$100 000 per hectare in regulating flood peaks (National Wetlands Group, 1988). Similarly the economic value of salt marshes dominated by *Spartina* on the eastern coast line of North America has been estimated at \$16 000–\$70 000 per hectare (Mitsch and Gosselink, 1993). An example of valuation techniques applied directly to a conservation problem is the cost-benefit analysis of the Korup tropical rain forest reserve, which included estimates of indirect benefits such as control of flooding and maintenance of soil fertility (Ruitenbeek, 1990; Table 2). Through this analysis, a clear economic advantage was demonstrated in maintaining the area as a tropical rain forest reserve rather than exploiting it for agriculture.

Table 2. Cost-benefit analysis of the Korup tropical rain forest reserve (Ruitenbeek, 1989)

Direct costs of conservation		−11,913
Opportunity costs		
Lost stumpage value	−706	
Lost forest use	−2620	−3326
Direct benefits		
Sustained forest use	3291	
Replaced subsistence production	977	
Tourism	1360	
Genetic value	481	
Watershed protection of fisheries	3776	
Control of flood risk	1578	
Soil fertility maintenance	532	11,995
Induced benefits		
Agricultural productivity gain	905	
Induced forestry	207	
Induced cash crops	3216	4328
Net Benefit		
Project adjustments		1084
External trade credit		7246
Uncaptured genetic value		−433
Uncaptured watershed benefits		−351
Net Benefit—Cameroon		7545

Note: NPV £,000, 8% discount rate.

THE ROLE OF ECONOMICS IN CONSERVATION

The drawing of economics into the analysis of conservation problems is probably one of the most important single steps that can be taken in strengthening the case for conservation. While it is idle to pretend that economic valuation will solve the biodiversity crisis, there are two very strong reasons why an economic analysis is helpful: first, it demonstrates that biodiversity is of measurable economic value, and second, it reveals the economic and social pressures which pose a threat to biodiversity.

Biodiversity is of measurable value to the economy

For some conservationists the process of valuation is unpalatable and arbitrary (Ehrenfeld, 1988). Norton (1988) suggests that the issues at stake are almost too important for economics: 'It is one thing to treat valuation of biodiversity as a guessing game or as a set of very interesting theoretical problems in welfare economics. It is quite another thing to suggest that the guesses we make are to be the basis of decision making that will affect the functioning of ecosystems on which we and our children will depend for life.' Many, however, would argue that if we cannot express the value of biodiversity in economic terms, then there is a real danger that decision makers will assume that it is unimportant. Indeed, we need to change economic practice and incorporate the concept of the value of biodiversity (and of other natural resources such as soil) into our accounting systems. Repetto (1993) argues that there is a dangerous asymmetry in the way we measure, and hence, the way we think about the value of natural resources. 'Man-made assets—buildings and equipment, for example—are valued as productive capital, and are written off against the value of production as they depreciate. This practice recognises that a consumption level maintained by drawing down the stock of capital exceeds the sustainable level of income. Natural resource assets are not so valued, and their loss entails no debit charge against current income that would account for the decrease in potential future production. Ironically, low-income countries, which are typically most dependent on natural resources for employment, revenues, and foreign exchange earnings are instructed (by the United Nations system of national accounts) to use a national accounting system that almost completely ignores their principal assets.' The consequence is that many developing countries are suffering devastating deterioration of their natural resources. For example Costa Rica has eliminated 30% of its highly diverse tropical forests in the past 20 years at the expense of massive soil erosion. Most of the forest was simply burnt to clear land to the relatively unproductive pastures and hill farms, thus sacrificing both valuable tropical timber which could have been harvested sustainably, and an enormous diversity of plant and animal species (Repetto, 1990, 1993). Examples like this illustrate the close identity that exists between the interests of the conservationist and those concerned with sustainable economic development.

Economic analysis reveals the pressures that work against conservation

According to Farber (1991) economic and political institutions have failed to provide proper incentives for sustaining ecosystems for five major reasons: short time horizon, failures in property rights, concentration of economic and political power, immeasurability, institutional and scientific uncertainty. This is a useful framework for our discussion, and we consider each reason separately, though in practice they are interrelated.

Short time horizons

The sustainable use of any natural resource implies that nothing should be done in the short term which reduces the ability of the resource to provide services in the future. However, there are strong economic forces which tend towards the destructive exploitation of biodiversity at the expense of its future use. Short time horizons of people, and politicians in particular, lead to discounting the future (i.e. the down-valuing of benefits which are obtained in the future). In the economics of the market place it makes sense to liquidate renewable natural capital if growth in the capital is less than the prevailing rate of interest. However, the relationship between interest rates and conservation interests is ambiguous. Norgaard and Howarth (1991) describe it as 'the conservationist's dilemma': 'Though high interest rates discourage the long term management of slow growing resources (forests) and the protection of long term environmental assets (biodiversity), high interest rates also discourage investment in projects which transform environments (dams) and in projects which are necessary to extract resources (oil wells).'

An example where interest rates have clearly been harmful to the conservation interest is the Japanese-dominated trade in tropical timber. The high interests that Japanese firms must pay on invested capital requires quick cash flow (Repetto, 1990). Thus, the high discount rates in developed countries affect in a negative way the management of a developing country's assets (Krautkraemer, 1995).

Competition in markets also shortens time horizons. For example, competitive forces in agriculture may induce farmers to take short-term perspectives for financial survival. Farmers must maintain yields and cash flow and this has led to adoption of high-yield crops, monoculture farming, and reduction in genetic diversity. It has been responsible for great intensification of agriculture, even when this may in the long term be harmful (Norgaard, 1988).

Failures in property rights

The classic example of a failure in property rights is the so-called 'problem of the commons'. According to traditional economics, when resources are not individually owned, then there is no individual interest in maintaining or improving the resource. 'A farmer knows that grass not grazed today will be gone tomorrow' (Farber, 1991). It should, perhaps, be added that considerate management of natural resources is not necessarily impeded by the absence of private ownership but by the absence of any ownership, including efficient forms of collective (e.g. tribal) ownership (Berkes, 1989). The traditional economic view that there exists *either* open access (and thereby overuse) *or* private ownership (and thereby rational management) ignores well-functioning collective arrangements.

Where property rights are not well-defined, or where, for some reason such as political instability, an owner cannot expect to enjoy the benefits over an extended period, there is a strong tendency towards the destruction of potentially sustainable ecosystems. For example, in countries such as the Philipines and Brazil, land tenure policies existed whereby individuals obtain titles or rights of occupancy only when they have cleared the land. The consequence of this conditional land tenure has been an accelerating loss of primary forest (Farber, 1991). Similarly, the 20 year lease on forest concessions in Indonesia provides insufficient incentive to replant or to make long-term investments. Since the lease period is shorter than the 35-year forest regeneration cycle, the very concessions lead to a drastic deforestation in the areas concerned (Krautkraemer, 1995).

A more subtle and complex problem relating to ownership is that biodiversity often benefits society as a whole, while the costs of preserving it fall upon the individual. For example, while there may be great advantages to a community in preserving wetland because of the ecosystem services it provides, for the landowner it may be financially advantageous to drain the area and develop it in some way. Indeed, Pearce and Moran (1994) suggest that 'the main reason for the erosion of biodiversity is that there is an underlying disparity between the private and social costs and benefits of biodiversity use and conservation'.

Concentration of economic and political power

In the developing world, extreme inequalities in the distribution of income and assets are both a cause and a consequence of biodiversity loss (Heywood and Watson, 1995). On the one hand, concessions or development rights are often given to politically connected or wealthy individuals who exploit the resource at the expense of the traditional occupants of an area. On the other hand, the poorest individuals and societies, for whom survival is a constant struggle, cannot afford the longer term perspective which is necessary to conserve organisms and their environment (see e.g. Nations, 1988). At a global scale, an equitable distribution of income and assets must be an important component of any strategy to conserve biodiversity.

In developed countries, activities adverse to conservation are often not strictly the result of economic disincentives or true 'market failure' but of deliberate political action or 'policy failure'. Numerous examples exist, including agricultural policies which lead to excessive intensification (even when food surpluses exist) and questionable works of infrastructure such as major roads and hydroelectricity schemes. An important task for economists is to calculate not only the ecological losses involved, but also the economic efficiency losses arising from this kind of policy.

Immeasurability
The problem of measuring the value of biodiversity is one of the reasons that its value is often not fully recognised in economic planning. The reliability of valuation techniques for non-use values are disputed, even amongst ecological economists, and are viewed with great scepticism by policy makers. The need for simplicity in policy-making tends to favour the analysis based only on the directly measurable uses of biodiversity, such as harvesting and tourist use. Indirect uses, for example in providing ecosystem services or (even more contentiously) option or existence values, are not taken so seriously.

Institutional and scientific uncertainty
Probably economic value measurements will always understate the true economic value of biodiversity because of our lack of knowledge about the role of particular species or particular habitats in providing life support functions. Partly, this is a limit to our present knowledge: we have a very imperfect understanding of the role particular species play in ecosystems, and are not in a position to assign a precise value to them. More importantly there are things we can never know. How important will the existence of certain species be for the ecosystem stability under unknown conditions in the future? This kind of economic value is impossible to quantify because it is unlikely to be recognised until some disastrous event has happened, for example landslides consequent upon deforestation or loss of fishing grounds due to pollution.

CONCLUSIONS

We believe that the rescue phase of conservation is coming to an end, and that the whole emphasis of conservation effort must inevitably change. Even in Europe, where our knowledge about biological diversity is greater than anywhere else and where so much effort has gone into conservation, we see the continuing loss of species and populations. In the tropical regions the situation is far worse; it is inevitable that a significant proportion of the flora and fauna will become extinct in the next few decades, much of it unknown to science. Against this background, and with the additional and largely unpredictable effects of climatic change, it will simply be impracticable to rely upon a museum-type approach to conservation, in which we attempt to preserve representative examples of all species and habitats.

Protected areas, nature reserves and national parks will obviously always be important. In them we will be inspired by the finest examples of biological diversity which existed before the devastating environmental changes of the recent past. They will continue to be important as living laboratories which help us to understand better the importance of species in functioning ecosystems. However, the main effort of conservation must shift towards the environments in which we live (Folke *et al.*, 1996). This concept was clearly recognised in the World Conservation Strategy (IUCN, 1980) which showed that over-exploitation of resources, loss of genetic diversity and damage to ecological processes and life support systems have dangerously reduced the planet's capacity to support people in both developed and developing countries. For this reason it sought a new partnership between conservation and development, to meet human needs now without jeopardizing the future, and called upon each country to prepare a national conservation strategy tailored to its own particular problems and characteristic cultural and economic conditions in order to achieve this (Johnson, 1983). This much broader concept of conservation was also recognised in the Seville Strategy for biosphere reserves. 'Thus biosphere reserves are poised to take on a new role. Not only will they be a means for the people who live and work within and around them to obtain a balanced relationship with the natural world, they will also contribute to the needs of society as a whole by showing a way to a more sustainable future. This is at the heart of our vision for biosphere reserves in the 21st century.'

Some readers may object that the examples presented here of ecosystem services fail to demonstrate that the conservation of species diversity is necessary for our survival. It could be argued that many ecosystem functions are possible even with a very impoverished biota: a wetland may improve water quality even without the help of rare orchids! We see two kinds of answer to this criticism. One is purely pragmatic: if we protect natural areas because of the ecosystem services they provide, we will, incidentally, help to preserve many species, even though they may have no important role in maintaining those services. The second argument concerns the state of our scientific knowledge: we simply do not know how important species diversity is for the long-term stability of ecosystems; if for no other reason, prudence would urge the preservation of as much diversity of as possible. The issue was vividly described by Ehrlich and Ehrlich (1981), who likened species in an ecosystem to the rivets holding an aeroplane together. The removal of rivets beyond some unknown threshhold number may cause the aeroplane, or the ecosystem, suddenly and catastrophically to collapse. The question of the importance of diversity for sustainable ecosystem function has now become the topic of intensive scientific research (Lawton, 1994; Johnson *et al.*, 1996).

It is also essential to develop our understanding of the importance of wildlife resources in economic terms. However imperfect and incomplete it may be, an economic valuation of such resources demonstrates, in terms that decision makers can understand, our essential dependence upon biological diversity. However, it should not be taken to extremes; there are things that economics cannot do, and never will be able to do. We should not pretend that we can estimate the value of every species (Daily and Ehrlich, 1995); nor can we use economic analysis to capture the intrinsic or moral value of a species to exist (Pearce and Moran, 1994). Perhaps the most practical way forward is for both ecologists and economists to focus their effort upon the overall value of ecosystems. As well as helping to preserve the integrity of ecosystem services, this is also the most effective way to preserve the diversity of species which they contain.

In conclusion, it is evident that the need for conservation has never been greater. However, in the future the motivation will not simply be the interest and beauty of wildlife, but the fact that we depend upon it. If we are to achieve sustainable development, conservation must cease to be the sole preserve of enthusiastic specialists, and become part of the economic fabric of any country.

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