THE ECONOMIC IMPLICATIONS OF A MULTIPLE SPECIES APPROACH TO BIOECONOMIC MODELLING

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ABSTRACT

Human activity frequently leads to the endangerment or extinction of other species. While ecologists study the biological facets of species loss, economics, as the science of understanding people's behaviour, has been charged with investigating the incentives underlying the actions people take that lead to this loss. One approach economists have taken to gain this understanding is to develop models of endangered species that include both economic and biological components, known as bioeconomic models. While ecologists frequently note the importance of modelling entire ecosystems rather than single species, most bioeconomic models in the current literature focus only on a single species. This thesis addresses the economic significance of this assumption through the development of a series of multiple species models and demonstrates, using African Wildlife as an example, the importance of interrelationships and economic values to the survival of endangered species.

From these models one can infer the conditions under which a single species model may be appropriate, at least in general terms. If species are independent, and either the opportunity cost of capital or the value of habitat is very low relative to the value of the species in question, then a single species model may yield results similar to that of a multiple species model. In contrast, if species are independent and these additional conditions are not met, a single species model may significantly underestimate both optimal stock levels and land allocation.

However, species do not live independently; they interact with species with which they share habitat and, when species interact, the potential for misapplication of the single species framework is even greater. When species compete, the single species framework consistently produces higher stock levels than the multiple species framework, the greater the level of competition the greater the difference. In a predator-prey relationship, the relative values of predator and prey are critical to determining the outcome of the multiple species model.

It is demonstrated that the inclusion of at least all economically valuable species in an ecosystem is important when constructing bioeconomic models. Using single species models where multiple species are economically significant could lead to misleading results and ultimately to incorrect policy decisions.

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Background and Objectives

As we begin the twenty-first century, the earth faces unprecedented levels of species loss. The World Conservation Union's (IUCN) Red List of threatened species currently contains in excess of 11,000 species of plants and animals, including 24 percent of mammal and 12 percent of bird species, all facing a high risk of extinction in the near future. In the four years from 1996 to 2000, the total number of threatened animal species has increased from 5,205 to 5,435 (IUCN, 2000).

Although species extinction is by no means a new phenomenon, this current 'wave' has a crucial distinction from those that have come before - the cause is anthropogenic in origin. Human activity, whether through deliberate exploitation, conversion of habitat, or the introduction of new species, has undeniably led to a decline in the number of species in existence. In fact, in the last 500 years, human activity has forced 816 species to extinction (103 since 1800), suggesting a rate of extinction some 50 times greater than would occur 'naturally'. Moreover, given the large numbers of species that remain unidentified (many species are lost before they are even discovered), these estimates are generally considered to be low (IUCN, 2000).

The loss of a species represents the loss of an opportunity. Once extinct, any potential use of that species, whether as a cure for disease, a source of food, or simply a source of appreciation, is gone. Species such as the Rosy Periwinkle *(Cantharanthus roseus)*, a plant from the tropical-dry forest of Madagascar (a key component in the treatment of Hodgkin's disease and childhood leukemia), have the potential to yield significant financial (and social) returns. Estimates suggest up to 80 percent of the world's health problems are treated by plant-based medicines, making the preservation of species not simply an altruistic concern, but a selfish one, directly contributing to our own wellbeing (IUCN, 2000).

Leading the way in the study of species loss is the field of ecology. Ecology emerged as a sub-discipline of biology in the early 1970s and can be defined as '...the scientific study of the interactions that determine the distribution and abundance of organisms' (Krebs, 1972, p.7). Ecology deals with three levels of concern: the individual organism, which addresses how individuals are affected by (and how they affect) their biotic and abiotic environment; the population (consisting of individuals of the same species), which deals with the presence or absence of particular species, with their abundance or rarity, and with the trends and fluctuations in their numbers; and the community (consisting of a greater or lesser number of populations), which deals with the composition or structure of communities (Begon, et al., 1996).

In the early development of ecology, the sheer complexity of natural communities seemed to preclude analysis at the community level of organisation. Early quantitative studies focused on individual species, namely the population dynamics of single species populations; studies at the community level of organisation were for the most part purely descriptive. However, since the late 1960s there has been significant progress in the study of ecology at the level of whole communities. The development of sophisticated modelling techniques and computer programs capable of handling the complexity of interaction, together with increased rigour of analysis of field observation, have all led to widespread advances in understanding the structure and composition of ecological communities. In the discipline today it is almost gratuitous to note that any single species population exists not in isolation, somehow separable from the complexity of interactions around it, but as an integrated component within a greater 'whole' (Putman, 1994).

As the understanding of ecological communities has grown, so too has criticism of conservation efforts. Conservation efforts have traditionally focused upon the identification and preservation of a small number of charismatic species, and in many cases upon deliberate overexploitation by human beings as the cause of endangerment. The plight of species such as the White Rhinoceros *(Ceratotherium simum)*, the Giant Panda *(Ailuropoda melanoleuca)* and the Blue Whale (*Balaenoptera musculus*) are well documented and (comparatively) well funded. While these concerns remain valid, as our knowledge of the many and varied interactions among species, their habitat, and the environment has improved, the perception of the nature of the problem of species extinction has shifted. The issue of species loss has become a broader concern, a concern that includes the potential loss of millions of unknown life forms (Swanson, 1994).

The last 30 years have seen the development of a significant body of literature surrounding the conservation of ecosystems as opposed to single species. The terms 'biological diversity', or 'biodiversity',[1] have become commonplace, and conservation catchphrases have turned from 'Save the Whale' to 'Save the Planet'. This new focus culminated in the 1992 signing of the Convention on Biological Diversity (CBD), a global convention, a central tenet of which is the 'conservation of biodiversity' (United Nations Environment Programme (UNEP), 2001).

While the fields of conservation and population ecology have acknowledged this shift in emphasis, economics as a discipline has been slow to react. Economics is the science of understanding people's behaviour and the motivations behind that behaviour. Within the sphere of species conservation, economics has been charged with investigating the incentives underlying the actions people take that lead to species loss. Given the need to develop and implement appropriate and cost-effective conservation policy (over 70 percent of all endangered species are found in developing nations (UNEP, 2001)), it is crucial for policymakers and researchers to adequately understand these incentives. In short, understanding these incentives is essential to the development of appropriate conservation policy.

Ecologists have undertaken the challenge of investigating the biological implications of species interaction. The ecological implications of modelling species in isolation rather than as part of an ecosystem are now well documented (Pimm, 1991; Begon et al., 1996; Milner-Guilland and Mace, 1998). Economists, however, have largely failed to adequately address the economic implications, which may have a profound effect on the quality of policy advice offered. Inappropriate or ill-informed policy could result in the misdirection of limited conservation funds, directing them towards areas where they are not needed or, more crucially, not being directed to areas where species extinction is imminent.

To this end, it is crucial for policymakers and researchers to recognise the significance of the single species assumption when interpreting the results of single species models. The development of a generalised multiple species framework facilitates such recognition. This thesis seeks to take up the challenge of investigating

[1] Although many definitions exist, biodiversity can be taken to encompass 'the variety of life forms, the ecological roles they perform, and the genetic diversity they contain' (Murphy, 1988, p.71).

the economic implications of species interaction by exploring the introduction of multiple species into the traditional bioeconomic framework.

More explicitly, the objectives of this thesis are to: Develop an analytical model to identify incentives underlying human behaviour in a multiple species framework. Develop a numerical model to test the implications arising from the analytical model. Compare the numerical multiple species model with a single species model. Finally, determine the conditions under which a single species model can be used, and those under which a multiple species model is necessary.

Following convention, the harvest levels of each species are control variables within the models. Although non-consumptive use of species may earn significant revenues (in Kenya, Elephant viewing alone has been estimated to be worth US$25 million annually (Hearne et al., 2000)), for the most part consumptive values remain the dominant sources of income. Consequently, and to retain expositional clarity, attention is restricted to these values. Recognising the role that loss of habitat plays in causing species decline (habitat loss or degradation affect 89 percent of all threatened birds, 83 percent of mammals and 91 percent of plants (IUCN, 2000)), allocation of land resources is specified as an additional control.

The remainder of this chapter explores early perceptions of extinction and briefly discusses the five periods of mass extinction in geologic history. This is followed by a discussion on measuring rates of extinction and the causes, both proximate and fundamental, of current species loss. The concept of total economic value is introduced before the global policy response to date is evaluated.

Chapter 2 reviews the relevant literature, beginning with the works of the 'Classical' economists, before turning to early developments in the field of ecological modelling. The seminal works surrounding the economics of resource exploitation are discussed, followed by a review of the development of the field of ecological economics as a sub-discipline. Extinction modelling literature is then introduced, and the chapter concludes with an examination of the fundamental models upon which the models presented in this thesis are based. Beginning with Clark's seminal (1973) model of a sole-owner fishery, attention is then focused on Clark's later model (1990), which explicitly considers the possibility of the existence of a multiple species fishery. The final model presented is Swanson (1994), who seeks to bring the modelling literature 'onshore' through the inclusion of term's representing the additional resources required for a terrestrial (as compared to a marine) species survival.

A multiple species framework is introduced in Chapter 3, combining both ecological and economic theories of species interaction. The seminal works of Lotka (1925) and Volterra (1926) are used to illustrate the ecological rationale behind a multiple species framework, while production literature, in particular the theory of joint production, forms the basis of our economic approach to the model. The analytical multiple species model is developed and comparisons are drawn between the single and multiple species results, paying particular attention to the potential consequences of misapplying a single species model to a multiple species situation. Because a multiple species model is likely to be sensitive to the relationships of included species, three cases of species interaction are considered: ecological independence, interspecific competition and predator-prey.

In Chapter 4 functional forms are specified, parameters estimated and the model solved numerically. Species independence is illustrated using the African Elephant *(Loxodonta africana)* and the White Rhinoceros. The African Lion *(Panthera leo)* and the Blue Wildebeest *(Connochaetes taurinus)* serve as examples of predator-prey interaction, while the Impala *(Aepyceros melampus)* and Greater Kudu *(Trageelaphus scriptus)* illustrate the case of interspecific competition. The numerical results serve to enhance the generalised analysis. Furthermore, the numerical application allows the model to be tested against observable 'real world' phenomena.

Finally, Chapter 5 provides a brief summary, discusses conclusions drawn from the analytical and numerical analysis of the model, notes weaknesses and shortcomings of the approach taken, and suggests areas for further research.

1.2 The Decline of Species

1.2.1 Five Extinctions

Although the phenomenon of species extinction is now an accepted fact, this has not always been the case. Species extinction was for a long time considered impossible. The ancient Greek concept of plenitude, or completeness of the natural world, implies that no organism that ever existed on the Earth could ultimately disappear from its surface because their final extinction would leave an unbridgeable gap in the 'Great Chain of Being'. Eighteenth century naturalists knew, of course, that a wide variety of fossils had no counterparts among living organisms, but this apparent anomaly was commonly explained by an as yet inadequate knowledge of life on the Earth. It appeared reasonable to assume that the missing species could still be found alive somewhere further afield. It was only after Cuvier (1799) first described the fossils of Mammoths that species extinction was established as a fact. It was hard to believe that such large and prominent mammals could roam the Earth without ever being observed by travellers, yet the concept of plenitude could still be reconciled with the fact of species extinction by assuming, as in fact Lamarck (1809) did, that man is the sole agent responsible for species extinction (Hoffman, 1989).

However, it became undeniable in the early nineteenth century that species extinction had indeed taken place in the geological past (Hoffman, 1989). In more recent times palaeontologists, through the study of fossil records dating back some 600 million years, have concluded that the process of extinction appears to have been ongoing. Certain episodes stand out as so-called 'mass extinctions'. A mass extinction can be defined as a period of substantial biodiversity losses that are global in extent, taxonomically broad, and rapid relative to the average duration of the taxa involved (Jablonski, 1986). Historically, five mass extinctions have been distinguished: the Late Ordovician, the Late Devonian, the End Permian, the End Triassic and the End Cretaceous (May et al., 1995), the latter of which has generated the most public interest, primarily due to the fate of the Dinosaurs. The nature and cause of the End Cretaceous event remains the focus of intense debate between those who suggest that the event occurred over a matter of months as a result of an asteroid impact and those who favour a longer duration. Some evidence supports both hypotheses, although the former is more popular (Garland, 1989).

1.2.2 The Sixth Extinction?

The Earth appears to be entering an era of extinction that may rival or even surpass that which occurred at the end of the Cretaceous period. Some estimates suggest the Earth is currently losing 27,000 species per year, representing a rate of extinction approaching 10,000 times greater than would exist under 'normal' circumstances (May et al., 1995). This period of extinction has been labelled the 'sixth wave'; it is comparable to the big five mass extinctions, with one important distinction: for the first time in geologic history, a major extinction episode is being caused by the actions of a single species – *Homo sapiens* (Ehrlich, 1986).

The sixth wave can be broken into two discrete phases. The first began at the very end of the Pleistocene, shortly after *Homo sapiens* evolved out of Africa and modern humans began migrating and spreading throughout the world. The fossil record suggests more than half of the large mammals of the Americas disappeared in a wave of extinction at this period. Although climate change and secondary ecological effects are among the suggested explanations, evidence strongly favours human predation as the most likely cause (Alroy, 2001). Phase two of the sixth extinction began about 10,000 years ago with the invention of agriculture. Perhaps the single most profound ecological change in the history of life, agriculture meant that humans were no longer restricted by the ecosystem's carrying capacity, and so began to overpopulate (Eldredge, 1998).

Few scientists who study the loss of biodiversity doubt that we are facing another mass extinction. There is difficulty, however, in establishing the rate at which these extinctions occur. Estimating rates of extinction, whether they are anthropocentric in origin or naturally occurring 'background' extinctions, is the focus of much effort and regarded as crucial for the development of appropriate policy responses.

The fundamental barrier to making precise estimates of the number of species being extinguished is that we do not know the number of species originally present (Wilson, 1988). Three different approaches exist to estimating likely future rates of extinction. The first, and by far the most familiar, uses species-area relations in combination with current or projected rates of habitat destruction, typically tropical deforestation (for reviews of such projections, see Whitmore and Sayer, 1992). The second method, first devised by Smith et al. (1993), provides an estimate based on the current rate at which species in better studied groups are 'climbing the ladder' of the IUCN's categories of threat from 'vulnerable' to 'endangered' to 'probably extinct' to certified extinction. The third method, first presented by Mace (1995), uses the estimated probabilities of extinction as functions of time. While each method has its relative merits and shortcomings (for a full review, see May et al., 1995), their results are surprisingly similar; that is, they all suggest a rate of extinction of between 100 and 1,000 times greater than 'normal', with most estimates approaching the latter figure (May et al., 1995).

Counter to the figures given above is a new argument of whom a principle proponent is Bjorn Lomborg. In his work *The Skeptical Environmentalist* (2001), Lomborg asserts that claims of massive species extinction do not equate with the available evidence. Lomborg points out that the rate at which species have become extinct has fluctuated over the Earth's history, and the number of species has generally increased over time. In fact, never before have there been so many species as there are now. On the method of using species-area relations in combination with rates of deforestation to calculate species loss, Lomborg notes that the correlation between the number of species and area, formulated by the biologist E.O. Wilson in the 1960s and Wilson's 'rule of thumb' - *if the area is reduced by 90 percent, then the number of species will be halved* - was developed in the context of island habitats (Mann, 1991; Simberloff, 1992). He questions the validity of extrapolating these results across large and diverse types of habitat, observing:

> If islands get smaller, there is nowhere to escape. If on the other hand, one tract of rainforest is cut down, many animals and plants can go on living in the surrounding areas.
>
> (Lomborg, 2001, p.253)

The Skeptical Environmentalist has provoked a storm of controversy; *Scientific American* devotes eleven pages to a series of articles criticising the work (Rennie et al., 2002). Scientists have reacted angrily to his suggestion that they have purposely exaggerated the true extent of environmental problems. Thomas Lovejoy, the chief biodiversity adviser to the president of the World Bank, in his review of Lomborg's chapter 'Biodiversity' remarks:

> ...Lomborg seems quite ignorant of how environmental science proceeds: researchers identify a potential problem, scientific examination tests the various hypotheses...researchers suggest remedial policies - and *then* the situation improves. By choosing to highlight the initial step and skip to the outcome, he implies incorrectly that all environmentalists do is *exaggerate*. The point is that things improve *because* of the efforts of environmentalists to flag a particular problem, investigate it and suggest policies to remedy it.
>
> (Lovejoy, 2002, p.69)

Criticism notwithstanding (much of which seems directed towards Lomborg personally, rather than towards his thesis), there appears to be merit in his arguments, and the true extent of species loss most probably lies somewhere between the two extremes.

In addition to establishing the current rate of extinction, much attention has been given to identifying the cause. There is a general agreement that human activity is the principal driving force of species loss.[2] This force can be distinguished in terms of proximate (direct) and underlying (fundamental) causes.

The Global Biodiversity Assessment Group identifies three proximate causes of species extinction. These are, in order of importance, loss of habitat, the introduction of non-native species, and over-harvesting. The underlying cause is more complex and refers to the economic, social and cultural factors that lie behind the activities that lead to species loss (Barbier et al., 1994).

The most prevalent cause of extinction, and one which policy initiatives have in the large part failed to address, is loss of habitat. No organisms occur in all habitats, and most have quite narrow requirements, so it is inevitable that when habitats are destroyed, populations and eventually species become extinct. Determining the overall rate of habitat loss with precision is very difficult. Comprehensive numbers on total destruction of habitats such as clear-cutting of forests, ploughing of grasslands and draining of wetlands are not available. Nonetheless, the figures that are available give a feel for how extensive the destruction has been. Percentages of total forest area that has been lost are available for a sample of 40 African nations and range from 30 percent in Zambia to 91 percent in The Gambia, with an average of 68 percent. Losses in 14 Asian nations (excluding China) range from 34 percent to 96 percent with an average of 69 percent. India has lost some 78 percent of all its forests (World Resources Institute (WRI), 1990). Further to these losses, a significant number of forests that have survived thus far are threatened today. The WRI assessment found that 39 percent of the Earth's remaining frontier forests are endangered by human activities. Despite a large body of research devoted to analysing the sustainability of developed nations' use of forest resources (see, for example, van Kooten et al., 1999), the primary use of the world's wood is not as building materials or paper, but as fuel, with 63 percent of all wood harvested burned as fuel (WRI, 2000).

[2] Even Lomborg acknowledges '...mankind has long been a major cause of extinction' (2001, p.251).

Forest is not the only habitat to be disrupted; the extent of total habitat destruction varies among habitat types and regions. In the United States, virtually all of the natural grasslands have been lost. Many Western nations including Germany, the United States and New Zealand have lost substantial areas of wetland. About 75 percent of the coastal mangrove wetlands of India, Pakistan and Thailand are gone (Brown, 1992; WRI, 1992).

In addition to total destruction, the degradation of habitat quality, especially that of freshwater habitats where 12 percent of all animal species live, is also a major cause of species loss. Major disruptions to freshwater habitat include the building of dams and the excessive use of rivers for irrigation (Revenga et al., 2001). Measuring habitat degradation is significantly more difficult.

Competition from non-native plant and animal species represents a growing threat to natural ecosystems. Exotic 'invaders' currently threaten some 20 percent of vertebrate species. The growth of world trade has seen the dramatic increase of this 'bio-invasion', and it is now considered to be the second greatest threat to species (WRI, 2000).

A good example of multiple threats to a single species posed by a variety of introduced organisms can be found in the case of the Brown Kiwi (*Apteryx mantelli*). Introduced predators are the main threat. About 50 percent of Kiwi eggs fail to hatch; many are eaten by Possums *(Didelphis marsupialis)*, Stoats (*Mustela erminea*) and Ferrets *(Mustela putorius furo*). Of the eggs that do hatch, around 95 percent of chicks are eaten by Stoats and Cats (*Felis catus*) before they are six months old. Older birds can defend themselves from these predators, but they remain vulnerable to Dogs *(Canis familiaris)* and Ferrets (Kiwi Recovery Programme, 2002).

The overexploitation of resource stocks is often thought to be the main cause of species extinction. While this was a contributory factor in the decline of a large number of species during early periods of human expansion, even abundant species can become extinct in a relatively short period of time if exploitation is excessive; commercial exploitation is seldom, if ever, the sole cause of extinction.

The Passenger Pigeon (*Ectopistes migratorius*) showed a spectacular decline in number from several billion in 1810 to around 200 million in 1870, to one captive female only 40 years later, and finally extinction in 1914. This is frequently used as a classic example of overkill leading to extinction (King, 1987). However, Bucher (1992) presents a convincing counter-argument. He contends that the Passenger Pigeon became extinct primarily as a result of forest destruction and fragmentation, particularly in its northern breeding grounds. Habitat destruction, coupled with an absence of social cooperation among the birds in food finding at low densities, would have been enough to lead to their extinction even without human exploitation (du Plessis, 2000).

Nonetheless, many current examples of species being threatened by over-harvesting persist. In addition to the well-documented examples of species being harvested for their high value by-products such as ivory and hides, many endangered species, especially those in developing nations, are harvested for food. According to the IUCN, the practice of hunting wildlife for food affects 30 endangered species including Gorillas, Chimpanzees and Monkeys, posing a significant threat to their existence (Hearn, 2001).

1.3 The Economics of Species Loss

1.3.1 The Fundamental Forces

In attempting to address the global problem of species loss, it is necessary to look beyond the proximate causes and come to grips with the fundamental forces that lead humans to behave in such a way that leads to the endangerment and possible extinction of other species.

Pearce and Moran (1994) categorise the fundamental causes of species loss into three areas. First and most crucially, human population growth leads to increasing amounts of the base resource (land), being converted into non-conservation uses. Second, market failure, which is the failure to create markets or modify existing markets for species so that they fail to secure economic value to compete with alternative uses of the base resource upon which they depend for survival. Third, intervention failures, meaning government-provided incentives such as subsidies to farmers, which simply exaggerate the rate of return to the alternative use of land.

The notion of market failure leading to the loss of species is given comprehensive treatment by Panayotou (1992). Addressing the wider concern of environmental degradation, Panayotou identifies a number of market failures affecting the use and management of natural resources. Those most significant to the issue of species loss are as follows: ill defined or absent property rights, high transaction costs, myopic planning, and irreversibility.

A fundamental condition for the efficient operation of markets is that there exist well-defined, exclusive, secure, transferable and enforceable property rights over all resources, goods and services. Property rights are a precondition to the efficient use, trade, investment, conservation and management of natural resources. In the absence of such rights, an individual is unlikely to invest in the conservation or management of the resource, as securing a return to the investment is at best uncertain, and in many cases impossible. Markets emerge to make possible beneficial exchanges or trade between parties with different resource endowments and different preferences. Absence of well-defined property rights prevents markets from emerging as there is no owner who can demand a price, and in their absence deny access; moreover, there is no buyer who would be willing to pay a price as long as they have free access to the resource elsewhere (Panayotou, 1992).

Clearly, for the case of most endangered species, with the exception of those inside reserves or zoos, property rights are clearly lacking. In fact, many are characterised (in particular marine species) by an open-access regime where those wishing to obtain access are free to do so.

Unfortunately, the establishment of well-defined property rights will not necessarily bring markets into existence if transaction costs are very high. A good illustration of this is the problems wildlife managers in large African game reserves face with poachers. Here the property rights are clear, but the enforcement costs of those rights are prohibitive. A further example can be seen in New Zealand, which has the exclusive rights to a large marine fishery, but insufficient resources to prevent others from encroaching on those rights.

Natural resource conservation and sustainable development ultimately involve a sacrifice of present consumption for the promise of future benefits. Because of time preference, such an exchange appears unattractive unless today's sacrifice yields greater benefits tomorrow. Future benefits are discounted, and the more heavily they are discounted the less attractive they are; a high discount rate may discourage conservation altogether. If the market rate of interest accurately reflects the society's rate of time preference, then (except for the issue of irreversibility) an optimal outcome could result. However, in developing nations particularly, a short and uncertain lifespan, coupled with a 'hand to mouth' subsistence standard of living, leads people to adopt myopic time horizons and discount rates that result in short-sighted decisions in pursuit of survival, or quick profits at the expense of long-term sustainable benefits (Panayotou, 1992).

Central to this idea is the notion of inter-generational equity. It is clear that any change in biodiversity has implications not just for the present, but also for future generations. Although the preferences of future generations are unknown to us today, it would seem reasonable to assume that they will also attribute value to natural resources. Unfortunately, the choices we are making today may actually mean less biodiversity available for future generations. There is vigorous debate over the role inter-generational equity should play in conservation decisions. Those who value inter-generational concerns highly advocate a zero discount rate for projects with long-term benefit streams.

While many market decisions are made on the assumption that they can be reversed if the outcome is not as desirable as first supposed, this assumption does not hold true in decisions involving natural resources. Once a species becomes extinct, there is no turning back; in contrast, choosing to conserve a species preserves our options. Clearly there is a social value or shadow price for the preservation of options, although it is difficult to estimate.

There are reasons to suggest this shadow price may be high. Technical change expands our ability to produce ordinary goods, but does little to improve our ability to produce natural resources (with the possible exception of increasing extraction efficiency). Furthermore, as a nation's wealth grows, consumer's preferences tend to shift in favour of environmental services relative to ordinary goods (Krutilla, 1967; Panayotou, 1992).

Swanson (1994; 1994a) considers species loss to be a result of a failing to include particular species within the 'global portfolio' of assets. Further discussion of Swanson's thesis can be found in the following chapter.

1.3.2 The Value of Species

Given that species are becoming extinct at rates far greater than 'normal' and given that human activity is by far the most likely cause of these extinctions, it is not surprising that a considerable (but insufficient) amount of the world's resources are currently being devoted to conservation effort. Why are we attempting to save species? The answer to that question at the most fundamental level is because we derive value from their continued existence.

The economic value of something is measured by the willingness of many individuals to pay for it. In turn, this willingness to pay reflects individuals' preferences for the good in question. Valuation is therefore based on preferences held by people; it is anthropocentric in origin. The resulting valuations are in monetary terms because of the way in which preferences are revealed, i.e. by asking people what they are willing to pay, or inferring their willingness to pay through other means. Moreover, the use of money as a measure of value permits comparison.

Many people believe that biological resources possess intrinsic value; that is, they are of value in themselves, independent of humankind. Although it is important to recognise from the outset that both economic and intrinsic value exist, it is the former, in particular Total Economic Value (TEV), that I focus on here. This choice comes from recognising that it is economic value that has the most bearing upon the ultimate fate of a species.

The economic value of biological resources can be broken down into a set of component parts. In a conservation context, TEV can be seen as a measure of the benefit to humankind (given a set of individuals' preferences) of the continued existence of a species or ecosystem. TEV comprises both use and non-use values. A use value is a value arising from an actual use made of a given resource and can be divided into direct use values, indirect use values and option values.

Direct use values are fairly straightforward in concept, but not necessarily easy to measure. They refer to activities such as fishing and timber extraction or the use of plants for pharmaceutical research. Indirect use values correspond to the ecologist's concept of 'ecological functions', and might include such things as a forest's function as a carbon sink This value is stressed in the work *Paradise Lost? The Ecological Economics of Biodiversity* (Barbier et al., 1994). The authors point out that ecological functions are uncertain, and may support or protect economic activity and property far removed from the ecosystem generating the function, thus generating a value that may be significant, but is often intangible. Option values are those amounts that an individual would be willing to pay to conserve a natural asset for future use; that is, no use is made of it now, but use may be made of it in the future.

Non-use values relate to valuations of the resource unrelated to either current or potential future use. Existence value is based upon the observation that many people reveal a willingness to pay for the existence of natural resources through charities such as the World Wildlife Fund for Nature, without actually taking part (or intending to take part) in the direct use of the resource being conserved. To some extent, this willingness to pay may represent 'vicarious' consumption, such as consumption of wildlife documentaries and magazines, but studies suggest that this is a weak explanation for existence value. Empirical measures of existence values suggest that existence value can be a substantial component of TEV. Furthermore, it has been demonstrated that in many cases some existence value must be appropriated to the resource in order for extinction to be avoided (Pearce, 1993; Pearce and Moran, 1994; Moran and Pearce, 1997; Alexander, 2000).

1.3.3 The Global Policy Response

Response to the endangerment and loss of species has encompassed the efforts and resources of a wide range of groups of people. Governments, non-government organisations, businesses and individuals have all sought to make their contribution to conservation efforts. I will not attempt to provide an exhaustive review of the various policy efforts, choosing instead to focus on the international response.

An early attempt to use international legislation to promote wildlife conservation was the 1911 Fur Seal Convention, designed to deal with the problem of over-exploitation of the Fur Seals of the Pribilof Islands off the coast of Alaska. Such moves have led to several other conventions, including the International Convention of the Regulation of Whaling in 1946, still in place in a modified form today (International Whaling Commission, 2002).

During the 1950s, conservationists began to focus on the escalating international trade in both live animals and their products. At first this attention was narrowly focused on a small range of species including Spotted Cats (traded for their furs), Primates (used in medical research) and Crocodiles (killed for their skins). In time the concern widened. By 1960 there was sufficient international impetus for the

IUCN at its General Assembly to urge governments to take action. The IUCN's next General Assembly in 1963 passed a resolution calling for an international convention to address the issue. This was followed by a first draft of such a convention in 1964. The IUCN General Assembly in 1969 and the United Nations Conference on the Human Environment in Stockholm in 1972 provided the final motivation, and The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was born (Huxley, 2000).

Originally signed following a three-week conference in Washington DC. in 1973, CITES came into force two years later. The aim of the convention was to save wild species from extinction by means of the regulation and restriction of the international trade in wildlife. The main thrust of the convention was the establishment of a set of import, export and re-export controls on species listed in the three appendices, the most stringent of which is Appendix I, which includes "...all species threatened with extinction which are or may be affected by trade" and stipulates "Trade in specimens of these species must be subject to particularly strict regulation in order not to endanger further their survival and must only be authorized in exceptional circumstances" (Text of the Convention, Article II: Fundamental Principles, 2002).

For most of its existence CITES has been the major tool possessed by the international community for preventing the loss of species, and high expectations have been placed on it. At the time there was very little knowledge of the nature and magnitude of international trade in specimens of wild species. Nevertheless, there was a strong feeling that international trade was a significant cause of species decline.

CITES has proven tc be controversial since its inception, and 27 years later the treaty is still surrounded by controversy. Four developments over the last quarter of a century are important. Most importantly, there have been improvements in our understanding of the threats to wild species. The convention is founded on the assumption that the international trade in wildlife is an important threat to their continued existence. Indeed, it is the only threat it addresses. Part of the weakness of CITES is that it has not always been successful in enforcing its bans and regulations. A much more serious difficulty is that for many species international trade is not the primary threat. It is now recognised that other processes, in particular the loss of habitat, the introduction of exotic species, and the bush-meat trade, are much more significant; thus for many species the CITES remedy will be quite inappropriate (Hutton and Dickson, 2000; Martin, 2000).

Indeed, there is an argument that the policies offered by the convention have actually exacerbated the problem. This argument asserts that for investment in a species' conservation to take place, the species must be able to generate a monetary return, sufficient to offset the opportunity cost of using its habitat (and other base resources) in an alternative way. Imposition of trade restrictions, through cutting off a potential source of revenue, effectively undermines the ability of the species to generate a return, making it a less attractive 'investment' option (Swanson, 1994; Bulte and van Kooten, 1996).

A second development has been that developing nations have become more forceful in putting forward their own case. While the conservationists of developed nations largely created the original convention, southern African nations in particular have emphasised the need for conservation policies to provide tangible benefits to those who live closest to the wildlife. This view has been criticised by those who see it as providing a license for the unregulated exploitation of wildlife.

The third development has been an increasing emphasis on the social dimension of conservation. As the fate of wildlife is so closely entwined with changes in human society, a policy for wildlife is simultaneously a policy for society, raising questions of justice and equity within the distributions of the costs and benefits of wildlife. The growing popularity of the notion of sustainable development, with its acknowledgement of a linkage between environment and social concerns, has served to fuel this debate (Hutton and Dickson, 2000).

A final development was the signing of the CBD. Signed at the United Nations Conference on Environment and Development in 1992, the CBD, like CITES, is concerned with the loss of species, but it is a more comprehensive convention, and one that takes into account the lessons of recent years. It does not focus on just one threat to wildlife, and it does not offer just one remedy. The convention has three goals: the conservation of biodiversity, the sustainable use of the components of biodiversity, and the sharing of the benefits arising from the use of genetic resources in a fair and equitable way (UNEP, 2001).

There is a consensus that CITES needs to move closer to the CBD. In light of the fact that the goals of the two coincide and that comparison between the two favours the latter, there is a strong case for subsuming CITES within the CBD. It should not be too surprising that the CBD should provide a better framework for conservation. It has had the advantage of twenty years of progress in conservation thinking and practice. The CBD possesses all the ingredients for a holistic approach to conservation and sustainable use. It is a force for the decentralisation and devolution of responsibilities to local communities, both in the developed and developing world. Its recognition of the need for incentives for people and the placing of economic value on wild resources puts it in the category of 'conservation with a human face' as opposed to the 'command and control' regime of CITES. Although at this point in time CITES remains independent, the eventual merging of the two seems inevitable (Bell, 1987; Martin, 2000).