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GLOBAL CHANGE AND BIODIVERSITY LOSS: SOME IMPEDIMENTS TO RESPONSE

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Preface

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EXECUTIVE SUMMARY

Many scientists believe that Earth's physical and biological systems are undergoing fundamental change. Although much is uncertain, changes in important biosphere-atmosphere feedback mechanisms may affect basic biological processes resulting in shifts in agricultural growing belts, reduction and poleward shifts of northern hemisphere forests, and possibly even mass extinctions. An effect of these changes may be a loss of biological diversity ("biodiversity"). This paper discusses the value of biodiversity and identifies some societal impediments to responding to its loss. We also offer some policy recommendations which may help us to better respond.

The concept of biodiversity is intuitively simple but surprisingly difficult to define. Generally, biodiversity refers to the variety and variability among and within living organisms and the ecological systems in which they occur (U.S.OTA 1987). However, there is no general agreement on the exact definition nor on why we should value biodiversity. There is also much debate about economic, cultural, scientific, and philosophical arguments for establishing the value of biodiversity. These conceptual problems are in part responsible for the difficulties we encounter recognizing biodiversity loss, and explain why we have largely failed to respond to it.

Sound policy must be based on relevant and useful information. However, the transfer of such information among the societal groups involved in the decision process, the scientific community, policy makers, and the general public, has been slow and inconclusive. In addition, the ecological consequences of present actions and policies may be long-term and spread out over vast geographical areas, making these consequences difficult to grasp. As

a result, government institutions, multilateral organizations, and nongovernmental organizations experience trouble knowing how to respond.

Recent policy attempts to deal with biodiversity loss have been fragmented. For example, legislation such as the Endangered Species Act mandates a reactive and atomistic approach to saving species and is thereby limited in its usefulness. This paper concludes with a discussion of some general elements we think are necessary to create effective biodiversity policy, as well as a few specific recommendations. For example, increased awareness that biodiversity loss is a problem, a renewed effort to determine the status of biodiversity, and suggestions for proactive rather than reactive policy could help us better manage threats to biodiversity loss.

I. INTRODUCTION

Many scientists believe that Earth's physical and biological systems are undergoing fundamental change (*e.g.* IPCC 1990). While natural systemic change has always been a part of our planet's history, many current changes appear to be caused largely by humans, and to be much faster than natural changes. Although these changes are not always readily apparent, they are potentially of great consequence. An increasing human population and rate of consumption place unprecedented strains on limited natural resources. Pollution, increasing as technological development outpaces our ability to dispose of the waste it produces, threatens critical land, water, and air resources. Even if nuclear, chemical, and biological weapons are not used, they pose threats to life because of dangers associated with their production processes. Ozone depletion, caused by the injection of chlorofluorocarbons into the atmosphere, threatens both human health and biological productivity. Perhaps most ominously, climate change, influenced by deforestation and the injection of carbon dioxide and other "greenhouse" gases into the atmosphere, may result in a climate regime unprecedented in the last 100,000 years.

In this paper we discuss the effects of anthropogenic global climate change on biodiversity, and we focus on human responses to this problem. Greenhouse warming-induced climate change may shift agricultural growing belts, reduce forests of the northern hemisphere and drive many species to extinction among other effects. If these changes occur together with the mass extinctions already occurring we may suffer a profound loss of biological diversity.

The concept of biological diversity ("biodiversity") is intuitively simple but surprisingly difficult to define precisely. Generally, biodiversity refers to the variety and variability within and among living organisms and the ecological systems in which they occur (U.S.OTA 1987; HR1268). However, because life is organized on many different levels ranging from the genetic to the ecosystemic, several different dimensions of biodiversity can be identified.

Genetic diversity refers to variety and variability at the cellular level, as in a specific gene pool. Genetic diversity allows a species to adapt to changing conditions, and it increases the range of possibilities for the future evolution of the organism. *Species diversity* refers to the number and variety of existing species. Although this is the aspect of biodiversity which is most familiar, it is problematic in that there is no universally accepted definition of "species" (Ruse 1988). Despite this difficulty, about 1.4 million species of plants, animals and insects have been identified, and between 5 million and 30 million species are estimated to exist (Wilson 1988). Although the exact number of species is unknown it is clear that extinction rates are increasing (Myers 1988; Lugo 1988). *Ecosystem diversity* refers to variety and variability at a higher level of organization, that of the ecosystem, which is a combination of plant and animal communities functioning holistically. Ecosystem diversity "embraces the whole collection of properties peculiar to renewable biological resources and it can, conversely, itself be regarded as a resource" (Ramade 1984, p. 15).

A comprehensive definition of biodiversity is difficult to formulate, both because there are so many levels at which biodiversity may exist and because it is difficult to distinguish between definitions and measures of biodiversity. It is important to note, however, that the holistic nature of biodiversity is of paramount importance. As Bryan Norton remarks, "Biological diversity is a much broader concept than genetic diversity. Biological diversity is not just constituted by the number of species, subspecies, and populations extant; it is also constituted by the varied associations in which they exist" (Norton 1987, p. 260).

In recent years concern about biodiversity loss has begun to move from the scientific literature to popular consciousness. Many reasons for this concern have been identified, including loss of resources, diminished opportunities for recreation, tourism, and research, and erosion of cultural heritage (U.S.OTA 1987). Scientists have been particularly concerned about the critical role that plant and animal life (the "biota") plays in maintaining the complex balance of life on Earth. Biodiversity loss at any level may affect the physical and biological processes we so greatly depend upon.

Global change threatens biodiversity because life is utterly dependent on its physical environment, and most life forms exist only within a narrow range of ecological conditions. Our concern in this paper will be to identify societal impediments to responding to biodiversity loss. We will begin by discussing the potential impacts of climate change on biodiversity, and the effects of biodiversity loss itself. Next we will address some problems in valuing biodiversity. Difficulties in recognizing biodiversity loss will then be considered. We will go on to evaluate the responsiveness of existing institutions to the problems we have identified, and, finally to draw conclusions and make recommendations.

II. POTENTIAL IMPACTS OF GLOBAL CHANGE ON BIODIVERSITY AND BIODIVERSITY LOSS

Systemic change has occurred throughout the history of the Earth, but many believe that change is now taking place at an unprecedented rate (Myers 1988; Lugo 1988). Many of these changes in Earth's physical systems can be attributed to human activity. Although there are many uncertainties about the magnitude and velocity of these anthropogenic changes, there is little doubt that they are occurring now and that they will have a profound effect on biodiversity.

Impacts of Global Climate Change on Biodiversity

Most scientists believe that we are already committed to a 1.5 to 4 degree centigrade warming of the Earth's mean surface temperature (IPCC 1990). Although the overall effect will be global warming, regional precipitation patterns, temperatures, and the likelihood of extreme events will impact different regions in different ways. Though these regional effects are not well understood, it has been suggested that on the North American continent there may be northward shifts of up to 300 km in agricultural growing belts (R.L. Peters 1989). Crop yields are expected to decrease in the Great Lakes region, the Southeast, and the Great Plains due to an increase in temperature, while an increase in crop yields is projected for the northernmost latitudes of Minnesota. Globally, an expansion of grasslands and deserts is expected to occur at the expense of forest and tundra. (UNEP/GEMS 1987).

Many factors can adversely affect the response of ecosystems and their constituents to climate change. Reduction in populations can reduce genetic diversity and consequently the ability of a species to adapt to changed environmental conditions. Temperature means and extremes, precipitation, soil type, soil moisture, and regional isolation affect both the actual distribution of species and their distributional limits (U.S.EPA 1988).

It is during the transition period from one climate regime to another that many species will be most vulnerable. In order to cope with changing climate, they will have to adapt or "migrate" to new areas. Climate change may often be too rapid to permit successful adaptation. Migration can be inhibited by species' lack of mobility as well as by physical barriers such as mountains, bodies of water, roads, cities, agricultural land, inappropriate soil type, and habitat heterogeneity (U.S.EPA 1988). In most areas migration corridors are not available for many species of plants and animals. Moreover, because of differing migration rates among species, ecosystems are unlikely to migrate intact. This disintegration of ecosystems may endanger species which otherwise could adapt to climate change.

Northern boreal forests are expected to shift poleward due to climate change. In the Eastern U.S., forests may migrate approximately 600-700 km within the next 100 years, while the southern range may die back due to increasing temperatures and drier soil conditions (U.S.EPA 1988). Because of the interdependency among species in an ecosystem, extirpation of a single tree species may adversely impact the rest of the organisms (birds, insects, plants, microorganisms, and mammals) in a forest ecosystem that depend on the tree species for food or habitat.

The pressure of climate change is likely to increase the already high rate of species extinction. Tropical deforestation, resulting from slash-and-burn agricultural practices, logging, and other human encroachment (Wilson 1988; Myers 1988) seems to be causing the destruction of about 17,000 species each year. In the world's rainforests approximately 375,000 to 1.25 million species are estimated to be threatened (deLama 1989). Although mass extinctions have occurred previously in Earth's history (Raup 1988), rarely have they approached the current rate and never before has human activity had such catastrophic effects.

Effects of Biodiversity Loss

Biodiversity cannot be equated with numbers of existing species; nevertheless, when species are driven to extinction, biodiversity declines. The impacts of biodiversity loss are wide-ranging. Some of these effects include changes in the composition of ecosystems. A reduction in the diversity of an ecosystem may result in both genetic and species loss as well as damage to the ecological processes that characterize the ecosystem (U.S.OTA 1987). For example, loss of soil fertility due to deforestation or desertification can reduce the kinds of crops that can be grown in a particular region. Soil erosion due to deforestation and desertification may reduce reliable water supplies by increasing runoff, thus decreasing water storage (U.S.OTA 1987; U.S.EPA 1988).

Changes in geochemical cycles may occur due to extinction or migration of plant and animal species responsible for cycling carbon, oxygen, nitrogen, and sulfur. The amount and availability of food sources as well as pharmaceuticals and fibers may be greatly reduced as the ecosystems, species, and genes which provide these resources are diminished (U.S.OTA 1987). Natural crop pollinators, pest predators, and weed control organisms may be lost as well. Declines in "resistance genes" (those which contribute to the resistance of crops to pests and pathogens), species that promote natural pest predators, and wild habitats that support pollinators, will make it difficult to protect crop species (U.S. OTA 1987).

Finally, changes or alterations in the food web could result from the deterioration of biodiversity. The removal of an organism at the top of the food web may have devastating effects throughout the web. (U.S.OTA 1987). An example is provided by the effects of ozone depletion on aquatic ecosystems. Depletion of the stratospheric ozone layer, as a result of man-made chlorofluorocarbons (CFCs) could lead to an increase in UV-B, ultraviolet radiation from the sun that is normally absorbed by stratospheric ozone. UV-B is able to penetrate clear water to a depth of a few meters, where it can damage algal chlorophyll, the chemical responsible in large part for photosynthesis. Single-celled algae occupy an important position at the top of the aquatic food web, and UV-B induced damage among algae would have repercussions throughout aquatic ecosystems (Smith et al 1980).

III. THE VALUE OF BIODIVERSITY

One of the most important impediments to preserving biodiversity is the difficulty of establishing and measuring its value. It has been argued that biodiversity should be preserved because such preservation is in our economic interests, because it contributes to scientific knowledge, because our cultural values demand it, and because a diverse world is better than a uniform one. In this section we discuss these reasons to value biodiversity and we note some of the difficulties which characterize the different values. In addition, we discuss some difficulties in making quantitative assessments of the value of biodiversity.

Economic Arguments for Valuing Biodiversity

Some have argued that biodiversity should be preserved because it returns economic benefits (Randall 1988, Farnsworth 1988, Iltis 1988, Wilson 1988). Economic literature describes several types of value including use-value, option-value, and quasi-option-value. Use-value is the extractive value of a resource, and is based on its market price. Option-value is the value of having the option to use something as a resource (Norton 1987). Quasi-option-value is the value of preserving options, given the expectation that growth in knowledge will produce new uses for species (Randall 1986; Norton 1987). For example, it is assumed that over time the number of species useful to the pharmaceutical industry will grow as advances in medical science occur, and as knowledge of how to use these species increases.

Economic arguments for preserving biological diversity are not altogether convincing. Few economists specifically address the value of biodiversity. Rather their concern is with the economic value of natural resources and even in this context some questions may be raised. While use-values of natural resources are fairly clear, option-values and quasi-option values are not. Indeed the assertion that there are such values may imply substantive ethical commitments (Norton 1988, Randall 1988). It can also be argued that economic considerations favor reductions in biodiversity, and that it is economics that is driving current biodiversity loss. Clark (1973, 1989) has shown in detail that in some sense it is economical to drive blue whales to extinction and invest the benefits in other productive enterprises, rather than manage blue whale populations in a sustainable way. From the point of view of economic theory, it is rational to drive species to extinction if present benefits are greater than discounted future benefits. Of course some may see this argument as indicative of a flaw in economic theory, rather than a comment on the value of biodiversity.

Critics of economic approaches to species preservation have argued against the use of a discount rate for future benefits (Parfit 1983). The notion guiding the discount rate is that a present dollar has greater value than a future dollar because it can now be invested and in the future it will be worth more than a dollar. Thus, when resources are treated as capital their future value must be discounted, and the value of the resource depreciated exponentially as the time period used in the calculation increases (Krutilla and Fisher 1975). On this approach, benefits spread out over the next century often turn out to be worth very little at present.

Cultural Arguments for Valuing Biodiversity

One influential argument for preserving the natural environment appeals to the cultural values of Americans (Sagoff 1974) and might be extended in such a way as to provide a reason for preserving biodiversity. On this view, Americans value the environment because our own national experience was shaped by confrontation with nature. Immigrants left the teeming urban centers of the "old world" to live in the unspoiled nature of the "new world". Indeed, the migration from the eastern to the western U.S. of the 1880s might be explained the same way. On this view the destruction of nature involves the destruction of our own cultural ideals.

Some may doubt whether environmental preservation really is an American cultural value. Even if it is, this argument would not provide a reason for preserving biodiversity on a global scale. Other societies may have different cultural ideals, and thus may have no reason to preserve biodiversity. However, if biodiversity is to be preserved it will take a global effort. Ecosystems do not admit of national or cultural boundaries, and any attempt at preservation must respect the boundaries of ecosystems, even if these conflict with political or cultural boundaries.

Scientific Arguments for Valuing Biodiversity

The scientific reason for valuing biodiversity lies in its value as the potential subject of knowledge. Due to human activity, genetic resources, species, and whole ecosystems are being destroyed before they can be cataloged and identified, much less studied. There are forms of life about which we will never have knowledge. With their extinction, opportunities for knowledge are lost forever. Yet, while this consideration has some force, its power can be denied. Some would flatly deny that knowledge is intrinsically valuable. Such an attitude, although not common in the scientific community, is very common in society at large. Many people believe that knowledge is valuable only insofar as it serves human ends.

This argument differs from the economic argument in that it makes no appeal to the economic benefits that knowledge may produce. On this view knowledge is intrinsically good, and biodiversity loss is bad because it reduces the opportunities for knowledge acquisition. This reason for preserving biodiversity is often given by scientists whose research is most directly affected by biodiversity loss (Ehrlich and Ehrlich, 1981). For someone who investigates tropical rainforests, the destruction of the forests may seem morally equivalent to the wanton destruction of a chemist's laboratory.

Even if it is agreed that knowledge has intrinsic value, this does not lead directly to recommending policies for preserving biodiversity. If such preservation were costless, then strong measures would be in order. But preserving biodiversity is not costless. People benefit from activities that result in the reduction of biodiversity. Its scientific value is a reason to preserve biodiversity, but it is not easy to say how strong a reason it is, and what weight it should have compared to other reasons.

Philosophical Arguments for Valuing Biodiversity

Two sorts of philosophical arguments have been given for valuing biodiversity. One argument, at least as old as the Aristotelian tradition, and highly developed during the medieval period, is that a richer, more complex world is better than a simpler, more uniform one. A second argument holds that it is wrong to kill many forms of nonhuman life.

There are at least two possible bases for the claim that a more complex world is better than a simpler one. One basis would be that complex worlds are objectively better than simpler ones, and that this in no way depends on the interests or purposes of valuers: it is an irreducible fact about value. A second basis for such a view would be to say that people place greater value on complex worlds than on simpler ones. On this view complex worlds are more valuable than simpler ones because people value them more highly. People may value them more highly because of their aesthetic value, or because of other interests that humans take in them.

Even if the view that more complex worlds are better than simpler worlds is correct, there is still a question about how much value complex worlds have in relation to simple ones. In order to "operationalize" such a view we would need a way of measuring degrees of complexity, and we would have to be able to map degrees of complexity onto degrees of value. Only in this way could we trade off the value of complexity against other values, such as those of economic development.

A second philosophical argument claims that it is wrong to kill many forms of nonhuman life. Taylor (1986) argues that killing a wildflower is just as wrong as killing a human. Stone (1974) holds that forests, oceans, and rivers should be granted legal rights. Callicott (1989) and Rolston (1988) argue that biological entities such as ecosystems and species have priority over individuals, and that in some cases the moral obligation to save plankton and bacteria is more stringent than the obligation to save human lives. On these views the destruction of biodiversity violates moral obligations that we have, and perhaps even the fundamental rights of other life forms. While such views are becoming more prominent in the intellectual community, they have been severely criticized (see *e.g.*, Regan 1981). However a modest variant of this view reaches similar conclusions in an indirect way. In recent years some philosophers (*e.g.* Singer 1986, Regan 1986) have argued that the same reasons we have for considering humans to be members of our moral community also apply to many non-human animals as well. If we were to accept such a view, we would perhaps acknowledge an obligation to respect the habitats of these animals, and this would lead to the protection of many plants and animals, and therefore the preservation of biodiversity.

Biodiversity may be valuable for a variety of reasons. We believe that the scientific and philosophical arguments for preserving biodiversity are persuasive and can be rationally defended. Although the arguments are complex and the scientific and philosophical values are difficult to quantify, this does not make biodiversity less important.

Measurement Problems

As a society we have a difficult time recognizing and respecting values that are difficult to quantify. This has led economists and others to try to quantify non-economic values so they may be represented in our decision processes. This is difficult because economics relies on the market or demand value of a resource as an indicator of its value. Biodiversity is not traded in a market, and therefore has no demand value. Moreover the most significant dimensions of biodiversity's value (the scientific and philosophical), are not related to its use as a resource.

In order to represent such values, economists have developed the notion of existence value. Existence value is the value attached to knowledge of something's existence, and is independent of any potential uses (Randall 1986). Economists measure existence value by creating a "shadow market", and thus a demand value, through the method of contingent valuation. Consumers are asked what they would be willing to pay to have the option to use a resource or to know that it exists. Contingent valuation allows the economist to assign dollar figures to values traditionally not measured in monetary terms. An abundance of literature exists which discusses the validity of this method. Although there are many different views, this literature suggests that contingent valuation does not accurately measure the value of non-resource goods (Boyle 1989, Brown 1984, Ehrenfeld 1988, Fisher and Hanemann 1985, Goodman 1989, Gregory 1986, Hanemann 1988, Knetsch and Sinden 1989, Norton 1986, 1987, 1988, Swartzman 1982, Tversky and Kahneman 1981, Weisbrod 1964). We doubt whether such studies could ever accurately measure the value of non-resource goods because it is far from clear that people value such goods in economic terms. For this reason there may be no right answer to many of the questions that are asked in contingent evaluation studies. At best, such studies may create economic values for non-resource goods, rather than discovering the values of the respondents. The values that are created may be an artifact of our techniques and have no validity. Sagoff (1981, 1984) has argued that the value that we place on goods such as biodiversity flows from our ideals and principles, and that it makes no sense to measure ideals and values in economic terms.

The problem of measurement, then, is that the considerations that make biodiversity important are not open to simple quantification. For this reason it is difficult to determine acceptable tradeoffs between biodiversity and other goods, or even to represent the value of biodiversity in the decision-making process. Although biodiversity is important, it is difficult to respect its value in the public arena.

IV. PROBLEMS RECOGNIZING LOSS OF BIODIVERSITY

We have claimed that loss of biodiversity is an important problem. We are already losing species at a very high rate, and climate change threatens to make this problem even worse. We have identified one problem in responding to biodiversity loss: the value of biodiversity is difficult to quantify and to trade off against other values. There are other problems as well. If we are to make adequate policy with respect to biodiversity loss, relevant information must be made available in a usable form. However, information is differentially generated and consumed among various societal audiences. In this section we discuss some issues about information transfer among these audiences, including scientists, the general public, and policy-makers.

Scientific Community

The issue of biodiversity was first raised by a small group of specialists including some members of the scientific community, as well as advocates from research organizations, universities, multilateral governmental organizations, and non-governmental organizations (NGOs) as well. Within this group, there is a high level of awareness about biodiversity issues. However, despite efforts to quantify biodiversity loss, even biologists and ecologists lack some very basic information. As Jenkins (1988) points out, the following information, at least, is needed in order to address the problem of biodiversity loss:

> . . . existence, identity, characteristics, numbers, condition, status, location, distribution, and ecological relationships between biotic species and biological communities or assemblages . . . (p. 231)

We will argue that most of the information available to biologists and ecologists concerns *numbers* of species, and that despite the high level of awareness of biodiversity issues, the scientific basis for thorough discussion is not yet secure. What follows is a discussion of some of the disputes among biologists and ecologists. Among the major sources of disagreement are the difficult and controversial quantitative assessments which concentrate on species rather than on ecosystems.

One example concerns species and gene counting: various investigations have yielded a wide range of results. While taxonomists have catalogued about 1.4 million species, it is estimated that between 5 million and 30 million exist (Wilson 1988), and some estimate the upper end of the range at 80 million (Brower 1990). However, an exact number has not yet been agreed upon.

Another example of controversial quantification is the calculation of potential rates of species extinction. Although he acknowledges that there is no way to know the exact rate of extinction, Myers (1988) suggests we can arrive at an estimate by applying the techniques of island biogeography to the number of species present in a habitat before deforestation. Such a calculation suggests that when 90% of a habitat is destroyed, 50% of the species will eventually be lost. Myers estimates that in the last 35 years 50,000 species have disappeared in Brazil and Madagascar, an extinction rate of about 1500 species per year. Wilson (1987) estimates that in tropical forests world-wide, a total of 10,000 species becomes extinct each year. And, according to Simberloff (1986), if deforestation continues at the present rate, 15% of all plant species and about the same number of animals species will be gone by the year 2000 (as cited in Myers 1988 and Lugo 1988). However Lugo (1988) argues that these estimates are not accurate:

> It is necessary to consider the effect of forest types on species abundance, the spatially selective (life zone) intensity of human activity, the role of secondary forests as species refugia, and the role of natural disturbances in maintaining regional species richness. At a regional level, one also has to consider the importance of exotic species in the maintenance of species richness, particularly in ecosystems subjected to the impact of human activity. This approach seeks balance by considering factors that maintain species richness as well as those that decrease it. Considerable research is required to provide sound estimates based on this

approach, because critical data concerning ecosystem function are not available in enough breadth to support enlightened management or policy making (Lugo 1988, p. 65).

There are other criticisms of extinction rate calculations. Because an extinction rate is expressed as a percentage one must have a base from which to calculate an absolute rate. However, as we have noted, scientists do not know the total number of existing species. The usual estimate given (Myers, Wilson 1988) is a range of 5 million to 30 million species. The high end of this estimate was derived by Erwin (1983, see also May 1988) who counted beetle species in a tropical forest. An assumption is made here that nature is uniform, and that one can generalize extinction rates across ecosystems. However, the biota are discontinuous in general, so there is no reason to believe that extinction rates are geographically uniform.

In addition to being inaccurate over geographic areas, calculation of an average extinction rate averages periods of high and low extinction, a process which may provide misleading information along the temporal dimension. David Raup writes:

> If . . . the Cretaceous-Tertiary extinctions took place over a time as short as a single year, then calculations of long-term rates become meaningless: during short intervals of extreme physical environmental stress, extinction rates were nearly infinite, whereas between these events, extinction rates may have been virtually zero . . . extinctions are point events rather than the result of a time-continuous process (Raup 1988, p. 54).

Rates of extinction among species also ignore a fundamental problem of taxonomy. There is as we have noted, a debate in the scientific community over what a species is (Ruse 1988). If it is not clear what constitutes a species, then it becomes even more difficult to estimate loss.

Finally, the ecosystem focus becomes lost in the process of counting species. Even if we know about the destruction of a particular ecosystem, we cannot identify which species have become extinct. Without a basic knowledge of the species composition of an ecosystem, quantifying loss of biodiversity based merely on the loss of an ecosystem is a difficult and perhaps impossible task.

Despite the lack of basic knowledge about extinction rates and species, it is apparent to the scientific community that human-caused biodiversity loss is occurring. Although lacking exact numbers, ecologists do possess a qualitative understanding of many issues involved in species extinction, and they recognize that a problem exists. However, the disputes within this community on the quantitative issues are passed on to the public and policy makers by the media and interest groups, resulting in an inconclusive public discussion in part because the underlying scientific understanding is weak. Finally, other than biologists and ecologists, most scientists may not differ greatly from the general public in their lack of understanding of biodiversity issues.

Policy Makers

Those in charge of developing and implementing policy face many of the same problems recognizing biodiversity loss as do ordinary citizens, and those similarities will be discussed in a later section. This section describes the unique problems policy makers encounter in recognizing biodiversity loss.

First, while the general public can take its time and choose whether and how to participate in the issue, policy makers are quickly forced to take a side when an issue arises (*e.g.* through a political initiative or increasing public interest). This means that a policy maker may have to take a public position on an issue without having had the time to study it thoroughly.

Second, biodiversity issues are likely to have a relatively low priority because they are perceived by policy makers as international issues rather than domestic ones, and therefore far from the concerns of the electorate. Elections do not turn on a candidate's position on biodiversity loss.

Third, biodiversity loss is a long-term issue whose consequences are remote. Our political system emphasizes short-term, domestic issues that correspond to election cycles. Problems that require long-term thinking are unlikely to rise to the top of the political agenda.

History may provide a clue as to why policy makers have trouble recognizing biodiversity loss. Previous attempts to focus attention on similar environmental issues have often dealt with individual species such as bald eagles, blue whales, and furbish louse-worts, resulting in legislation such as the Endangered Species Act. Such species do not serve as proxies for entire ecosystems, nor were they intended to do so by the legislation. While the Endangered Species Act addressed an important problem, and although the use of species as symbols (*e.g.*, owl vs. jobs) captures public attention, over the long term this approach has proven to be too narrow to address current problems of biodiversity loss. Focusing attention exclusively on single species can blur the very important issue of complex ecosystems as an embodiment of biodiversity. While the Endangered Species Act was important as a first step, there is now a need to focus on ecosystem issues.

General Public

In their role as citizens, policy makers and scientists experience many of the same problems recognizing biodiversity loss as does the general public. These groups have several problems in common.

First is the high rate of scientific, and particularly biological, illiteracy among the general public. While few people grasp the concept of "species", even fewer understand the relative importance of different species. It is known that bacteria and fungi are essential to the maintenance of ecological and evolutionary processes on earth (Odum 1983; Ricklefs 1979). Therefore, decomposers and other plant life situated at the end and beginning of the food chain are equally, if not more important than the few conspicuous species (*i.e.*, condors, rhinos, and pandas), which tend to receive most of our attention. However, because the public is highly ignorant of these relationships (and as a result of the legislative approach embodied in the Endangered Species Act), it continues to place great emphasis on saving a very narrow range of species.

A second problem, issue competition, can draw the public's attention away from biodiversity loss issues. The American public relies in large part on the popular media for information about issues such as biodiversity loss. In particular, the media is quite adept at providing America's large television audience with front row seats for the latest natural disaster, coup attempt, or airplane crash. Such sensational, short-lived stories often draw interest away from long-term problems such as biodiversity loss.

The American public is also less likely to pay attention because biodiversity loss resulting from global change is an abstract idea. However, integrating biodiversity loss with more tangible and familiar issues, may provide the public with a clearer message. One way in which this might be accomplished is to link deforestation and biodiversity loss to encroachment on the natural resources of a developing country by a multinational corporation. An example might be the destruction of tropical rainforest ecosystems in Central America by American fast food chains in order to raise cattle for consumption in the U.S. as hamburgers (Myers 1981; Uhl and Parker 1986). Such examples provide a way for the public to focus on an otherwise long-term, abstract problem.

Finally, while biodiversity loss may directly and immediately affect the lives of the general public, it does so invisibly. There are two reasons why it is difficult for the general public to recognize biodiversity loss as it is taking place. One is that the consequences may not be evident in the short term. For example, the gradual loss of natural crop pollinators, pest predators, and weed controlling organisms eventually results in crop destruction, but such losses may take several years to recognize and even longer to be felt by the public. The second reason we don't recognize biodiversity loss is that the American public has at its disposal a wide range of resources. So many, in fact, that the disappearance of one is rarely alarming because there are many readily available substitutes at present.

Loss of biodiversity is a problem spanning geographical and cultural boundaries, as well as time and value systems. It is a problem without easy solutions, and certainly without the quick fixes which capture the public's attention. There may be some partial solutions that appear easy in principle, however, these solutions are difficult to implement and to sustain, and it appears to the American public that there is little they can contribute to help alleviate the loss. This sense of helplessness in itself may prevent individuals from taking action.

In order for our political institutions to respond successfully, loss of biodiversity must first be recognized as a problem caused by anthropogenic global change as well as by damaging local activities. Information about biodiversity loss is not clearly understood or transmitted by the scientific community, the general public, or policy makers, and without a clear understanding of the problems, finding solutions is much more difficult. Problems with biodiversity issues are not restricted to societal groups mentioned earlier.

V. INSTITUTIONAL RESPONSIVENESS

Problems with biodiversity issues are not restricted to the societal groups mentioned earlier. For several reasons institutions also have difficulty responding constructively to biodiversity loss. First, as noted above, the ability to respond depends somewhat on the ability to recognize biodiversity loss. Second, because a constructive response might well involve fundamental changes, the flexibility required to address biodiversity loss is lacking in many institutions. Third, an effective response typically involves many institutions. Finally, solutions to biodiversity loss may be in direct conflict with other policies. For example, by vetoing legislation that would have provided the United Nations Family

Planning Agency with $15 million in U.S. support, the Bush administration has indicated that it does not support population control, although one possible cause of biodiversity loss is the increasing number of people dependent upon a shrinking natural resource base. Thus, encouraging population control, a potential partial solution to biodiversity loss, is in direct conflict with current administration policy.

The problems of institutional responsiveness are aptly summarized in the following comments.

> The objective of sustainable development and the integrated nature of the global environment/development challenges pose problems for institutions, national and international, that were established on the basis of narrow preoccupations and compartmentalized concerns. Governments' general response to the speed and scale of global changes has been a reluctance to recognize sufficiently the need to change themselves. The challenges are both interdependent and integrated, requiring comprehensive approaches and popular participation (WCED 1987, p. 9).

Although this paper is geared toward United States policy, some brief observations about the way other countries respond to biodiversity loss are illuminating. Not only has the United States failed to act on biodiversity issues, most other countries lack comprehensive plans to deal with these issues as well. A further distinction can be drawn between the reactions of developed and developing countries. In developed countries such as the United States the resources are available for attacking biodiversity loss, but as discussed above a variety of factors keep them from recognizing and understanding the loss and coordinating programs to address it. Like developed countries, developing countries haven't responded to long-term issues such as biodiversity loss, but for different reasons. Developing countries depend to a greater extent on their native biodiversity, and in the long run ought to be very sensitive to its loss. However, developing countries with short-term pressures to provide food and shelter are not likely to respond to a long-term issue such as biodiversity loss. They do not have the resources of the developed countries with which to address it. Finally, developing countries experiencing foreign debt crises may exploit natural resources at much higher levels than countries without debt (NSB 1989).

The problems that we have identified differentially affect government institutions, multilateral organizations, and nongovernmental organizations. We will discuss each in turn.

Government Institutions. U.S. government institutions have only recently been forced to consider global change issues such as biodiversity loss. Currently there is no Federal mandate for the maintenance of biological diversity. However, many government institutions have some responsibility for Federal ecosystem conservation programs, although most of these programs address and protect only those species recognized under the Endangered Species Act. In addition, Federal agencies interpret terms such as "biological resources", "wildlife", "animals", and "natural resources" in different ways. "Wildlife", for example, has a number of definitions including:

- mammals that are hunted or trapped
- all mammals; used interchangeably with "animal"
- all animals, both vertebrates and invertebrates, excluding fish
- all animals, both vertebrates and invertebrates, including fish (U.S.OTA, 1987)

Federal agencies may have dichotomous missions (Clarke and McCool 1985), or conflicting mandates. An example is the Department of the Interior under which the National Park Service and the Bureau of Land Management (BLM) operate with almost diametrically opposed mandates. The Park Service was established to conserve, while the U.S. BLM has shifted toward development and production of natural resources (Clarke and McCool 1985).

In addition, the mandate of the Park Service is itself dichotomous, encompassing both preservation and use. The mandate is to:

regulate the use of . . . national parks and monuments . . . conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (as cited in Clarke and McCool 1985, p. 49).

In addition, the missions of agencies such as the Fish and Wildlife Service and the Bureau of Land Management are to conserve for economic, rather than preservationist ends. For the Fish and Wildlife Service this means that game fish and animals are of highest priority. For the Bureau of Land Management, it means that land will be leased for oil and gas exploration or to graze cattle, rather than for ecosystem protection. The result is an uncoordinated, noncomprehensive, and sometimes even counter-productive collection of programs.

Multilateral Organizations. Multilateral organizations, such as the World Bank, are also potential respondents to global change issues such as biodiversity loss; they act most often in developing countries. However, it is difficult for them to address the issue for a number of reasons. First, multilaterals are affected by the vagaries of international politics which can affect the funding and implementation of programs. For example, according to World Bank consultant George Honadle (1989), countries may be ranked for aid on the basis of their ability to spend money "productively" - their "absorptive capacity". However, absorptive capacity does not consider the environmental effects of those expenditures (Honadle 1989). In addition, difficulties are encountered when multilaterals try to impose institutional frameworks on developing countries.

Second, transnational problems also occur. For example, the efforts of a multilateral organization to address loss of biological diversity may be adversely affected because the multilateral usually works alone. Single organizations have difficulty influencing all the actors necessary to effect significant changes (Honadle 1989). This means that often little is accomplished toward solving transnational problems by multilateral organizations that operate alone.

Third, the exchange of scientific information occurs largely among developed nations, rather than between developed and developing nations (NSB 1989). In addition, on an international scale, politics may push science, including research on biodiversity, to a lower priority level.

Finally, multilateral organizations may have dichotomous missions, as in the case of development agencies which fund projects both to develop (build dams and roads) and to conserve, thus creating conflict and ultimately hampering the preservation of biodiversity.

Non-Governmental Organizations (NGOs). NGOs such as World Wildlife Fund, World Resources Institute, Conservation Foundation, Environmental Defense Fund, Friends of the Earth, National Resources Defense Council, National Wildlife Federation, The Nature Conservancy, and the Sierra Club are advocacy groups. Such groups are most attuned to global change and the problem of biodiversity loss, and have had the most success responding to the loss. Unlike government and multilateral organizations, NGOs have the flexibility to administer their programs most effectively. NGOs are also able to launch demonstration projects which governments can later administer. In the United States, advocacy groups have the power to litigate on biodiversity issues.

Despite these advantages NGOs are limited by their own economic constraints because they are dependent upon grants and donations. In addition, issue selection tends to drive programs and issues may be selected on the basis of their appeal to donors. Although the public may respond to the plight of the appealing panda, it is less likely to take an interest in and contribute to projects directed to ecosystems.

VI. RECOMMENDATIONS

The previous discussion indicated that the preservation and maintenance of biological diversity are important, and that a comprehensive policy for preserving biodiversity should be developed. The fact that the most important reasons for valuing biodiversity are scientific and philosophical, and therefore difficult to quantify, does not make biodiversity less important. Indeed, arguably it makes biodiversity more important. For biodiversity, rather than gaining its value from its impact on our standard of living, is in a domain that transcends economics. Future generations may forgive us for bequeathing them a large national debt but they may never forgive us for destroying Earth's irreplaceable stock of biological resources.

The biodiversity loss that is now occurring and may accelerate in the future is largely anthropogenic in origin. It can be attributed to increasing population, pollution, production of nuclear and biological weapons, exploitative economic development, and climate change. For this reason policies responsive to biodiversity loss must be directed toward controlling human behavior. Furthermore, such policies must specifically be directed towards preserving particular gene pools, species, and ecosystems, but they must also respond to the facts of systemic anthropogenic global change. Otherwise immediate successes in preserving biodiversity in dedicated parks and wilderness areas may be wiped out when climate change makes it impossible for the organisms that we are trying to protect to survive in their designated areas.

Any recommendation must recognize that policy takes place on different levels in both national and international arenas. We describe first some general elements of a policy addressing loss of biodiversity. Next we discuss more specifically the kinds of programs and improvements that can be established at the levels of federal institutions, multilateral organizations, and NGOs.

General Policy Elements

There are four general elements necessary for creating an effective biodiversity policy. The first element advocates an increased awareness of the sources of the problem. The second addresses technical issues of definition and information gathering. The third and fourth concern changes of approach to the problem of biodiversity loss.

Identify the Source of the Problem. As we have already suggested, it is important for us to identify the exact problem our policies are supposed to address. This is especially crucial with respect to biodiversity loss, because this issue is entwined with other important issues, including sustainable development and global change. Preserving biodiversity is not the same as preserving endangered species, and given the facts about global change, atomistic policies directed toward species preservation are not likely to be sufficient for preserving biodiversity. Before we can design policies that are adequate for preserving biodiversity, we must be clear about exactly which problems we are trying to solve.

Develop Better Definitions and Data. The second element of our policy recommendations concerns the efforts to determine the status of biodiversity. We have pointed out difficulties in defining key concepts, such as "biodiversity" and even "species". We have also shown that, despite qualitative and anecdotal data, our quantitative database about biodiversity loss is surprisingly weak. These problems suggest that both empirical and theoretical research must continue. We need to develop better theories, concepts, and vocabularies with which to address this problem. We also need more information about what is occurring on the ground. Because biodiversity levels are always changing, we must continue to monitor its status.

One way to do this is to establish global bioinventory databases for plants, animals, and microorganisms on both national and international levels. Monitoring and collecting programs such as UNEP's Global Environmental Monitoring System (GEMS), the

International Board for Plant Genetic Resources Program (IBPGR), and the Nature Conservancy's Natural Heritage Data Centers already exist, and these programs need to be continued and improved.

Transcend the Species Approach. The traditional approach to species loss is an individualistic one, exemplified by the Endangered Species Act. We suggest that while such an approach is useful for dealing with individual species, it does not address the holistic nature of biodiversity, "the varied associations in which [species, subspecies, and populations] exist" (Norton 1987, p. 260). As U.S. AID administrator Nyle Brady writes,

> . . . habitat conservation is the key to the effective conservation of the world's biological diversity. The utility or necessity of a species from the standpoint of humans is not necessarily a corollary of a species' adaptability. Therefore, conserving biological diversity for human benefit means conserving sufficient natural habitat for those species incapable of surviving elsewhere (1988, p. 410).

It is necessary to move beyond the individualistic, single species approach to one based on the ecosystem because,

> . . . attempts at snatching individuals from the jaws of extinction are analogous to treating the symptoms of a disease without curing the disease itself (Hunt 1989).

While her language may be harsh Hunt's point is well taken; the only way to ensure that organisms can continue their evolutionary processes is to ensure the protection of the ecosystems in which they live.

Become Proactive. Another characteristic of the traditional approach to species loss is that it is reactive. Under the ESA, the first step is to list a species. A species is listed as endangered when enough information is gathered to suggest that there is a significant decline in the population or range of the species, and after public review has been completed (U.S.OTA 1987, p. 228). The next step is the development of a formal recovery plan that outlines the responsibilities of all parties involved in protection of the species and management of its habitat. The recovery plan, which is not a binding agreement but simply an advisory document to the Secretary of the Interior, must then be approved.

The problem is that implementation of recovery plans is slow (Drabelle 1985, as cited in U.S.OTA 1987), and some animals may become extinct in the time period between their proposal as candidates and their review by the Fish and Wildlife Service (Bean 1985; Fitzgerald and Meese 1986, as cited in U.S.OTA 1987). The problem is inherent in the nature of the policy which is applied only after a problem is recognized.

This reactive approach should be modified in favor of a more proactive approach to preserving and maintaining biodiversity. A proactive approach would identify ecosystems that might become endangered in the future, and it would insist that preventive efforts be taken to ensure that none become endangered.

Any proactive program should have at least the following dimensions:

First, we should pursue a "tie-in" strategy with various approaches to limit or slow climate change (Jamieson 1990). Many of the policies that should be implemented in response to the possibility of global warming would help preserve biodiversity in two ways. First, they would help preserve biodiversity by slowing or inhibiting climate change and, as we have seen, climate change is a major threat to the preservation of biodiversity. Second, many of these policies would also have indirect effects that would contribute toward biodiversity preservation. For example, policies to slow greenhouse warming would reduce the use of fossil fuels. The cycle of fossil fuel development and use is extremely damaging to biological resources. For example, the transport of oil can lead to cataclysmic accidents of the sort that occurred in Prince Edward Sound in 1989. The use of coal has lead to an epidemic of acid rain in Europe and increasingly in North America, with catastrophic effects on lakes and boreal ecosystems.

A second dimension of a proactive approach is an educational one. As we have seen, issues about biodiversity loss are complex and often ill-understood. Regulation, legislation, and court decisions are certainly needed in this area, but ultimately the protection of biodiversity rests on a well-informed, well-educated citizenry. Science education must be improved, and people must also learn to think more rigorously about the long-term effects of many small actions. In addition to this we need to educate people to think more clearly about values, and we need more research about the nature of values and how they change.

Specific Programs and Improvements

As discussed in Section V, government institutions, multilateral organizations, and nongovernmental organizations all have the potential to respond to loss of biodiversity, but they face a number of difficulties in doing so. Despite the uncertainties and questions it is important to begin to formulate some ideas about how these institutions might better respond to biodiversity issues.

Government Institutions. While there is interest in funding biodiversity research, institutions of the United States government lack a federal mandate for the protection and maintenance of biodiversity. H.R. 1268, National Biological Diversity Conservation and Environmental Research Act, offered by Representative Scheuer would provide such a mandate,

> It is the public policy of the United States that conservation of biological diversity is a national goal, and conservation efforts are a national priority (sec. 5(a)) . . . The actions, policies, and programs of all Federal agencies shall be consistent with the goal of conservation of biological diversity, to the maximum extent practicable (sec. 5(c)).

In addition H.R. 1268 would

1) amend the National Environmental Policy Act of 1969 to require that environmental impact statements include the impacts on biological diversity;

2) establish a National Center for Biological Diversity and Conservation Research;
3) establish an Interagency Working Committee on Biological Diversity responsible for coordinating the Federal strategy for conserving biological diversity;
4) authorize agencies on the interagency committee to provide grants for projects to maintain and restore biological diversity; and
5) establish a permanent National Scientific Advisory Committee on Biological Diversity to oversee the programs mentioned above and to serve as a general reference and advisory resource for biological diversity issues.

We believe that passage of the Scheuer bill would be an important step in addressing problems that we have identified.

Multilateral Organizations. Like governments, multilaterals typically have apparently conflicting missions of conservation and development. However, current thinking reflects the idea that development and conservation are not necessarily mutually exclusive goals, and may actually depend upon each other (Benbrook 1989; DESFIL 1988; Gow 1989; Honadle 1989; WCED 1987; Martin 1988). For example, the World Commission on Environment and Development states that:

> . . . it is impossible to separate economic development issues from environmental issues; many forms of development erode the environmental resources upon which they must be based, and environmental degradation can undermine economic development (WCED 1987, p. 3).

In many cases a degraded environment is more difficult to develop than one that is in good shape. For example, Ethiopia seems to be cycling between drought and flood. Much of the agricultural land in Ethiopia is so eroded that rainfall only contributes to further erosion. Preserving biodiversity is part of environmental quality, and environmental quality is part of a larger network of values which includes economic development.

Ecology and economy are becoming ever more interwoven — locally, regionally, nationally, globally — into a seamless net of causes and effects (WCED 1987, p. 5).

Second, multilaterals are best equipped to support and orchestrate exchanges of information about biodiversity loss between developing and developed countries. The international data collection programs run by UNEP as well as the Man and Biosphere Program of UNESCO (implemented by the Department of State), the Tropical Forest Action Plan of the FAO, and the international convention sponsored by IUCN and UNEP are examples of programs through which information can be exchanged among nations (Miller et al 1989).

Finally, multilaterals must work together as well as with NGOs and government institutions in order to broaden the impact of their biodiversity loss programs.

Nongovernmental Organizations. NGOs have had the most success with biodiversity-loss issues and must continue their important work in this area. They should continue to be the voice for biodiversity loss issues by using their high profile to send the message to other institutions as well as the general public. Moreover, NGOs should continue their pilot programs and litigation on biodiversity issues.

A recent study by the World Resources Institute (Abramovitz 1989) surveyed U.S-based organizations on biodiversity research and conservation activities in developing countries. In 1987 $37.5 million dollars were spent on 873 projects in 86 developing countries. NGOs implemented the most projects, 40%, and were the second largest funder of projects, 24% (the U.S. government funded 53%). Some examples of projects include: the planning and establishment of protected areas in Peru by The Nature Conservancy; ethnobotanical studies carried out in Madagascar, Peru, Thailand, and Cameroon to document the cultural values of biodiversity, as well as the management of buffer zones around protected areas by the World Wildlife Fund, and research in plant systemics to increase the knowledge of plant species by the Missouri Botanical Garden (Abramovitz 1989).

The fact that NGOs are doing a relatively good job does not relieve governments of their responsibilities, however. Any effort to address biodiversity-loss issues must be an effort that includes governments, NGOs, and multilaterals. What we need is major structural change in the way that the world approaches biodiversity issues and thus requires the cooperation of all major players.

VII. CONCLUSION

In this paper we have discussed the problem of biodiversity loss, and identified some of the difficulties involved in our attempts to respond to it. We have also tried to show how this problem is related to that of anthropogenic global change, and have argued that these problems must be approached in concert. We have also made recommendations for responding to biodiversity loss, ranging from new legislation to educational initiatives.

One point that should not be lost in this discussion is that biodiversity loss is occurring now, probably at an unprecedented rate, and unless concerted action is taken in the near future biodiversity loss will cease to be an issue. It is likely that sometime in the twenty-first century, if present trends continue, we will have transformed the Earth, in all of its beauty and richness, into a domesticated monoculture. The plants and animals that persist will be those which are resources for humans, or are able to live on the margins of human activity. As we have tried to show, there are good reasons for wanting to avoid such an outcome. In order to do so, however, we will have to act now.

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