# The Value of Biodiversity: Markets, Society, and Ecosystems

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ABSTRACT. *The value of biodiversity is discussed at different levels including market value, nonmarket values to humans, and the value of biodiversity to ecosystems. The main conclusion is that, although market exchange values of environmental services may be used to justify biodiversity protection measures, it must be stressed that exchange value constitutes a small portion of total biodiversity value. The total value of existing biodiversity is largely unknown but indications are that it is essential to human existence. The various levels of biodiversity value point to the need for a hierarchical and pluralistic methodology to determine appropriate policies for its preservation.* (JEL Q21)

## I. INTRODUCTION

Among ecologists, there is a general consensus that biodiversity[1] is of critical importance to the health of ecosystems and even for the long-term survival of the human species. There is also a consensus that biodiversity is being lost at a rate which is a cause for concern.[2] Economists, on the other hand, generally view biodiversity as just another good which is to be placed in the basket of market choices just as any other. The discussion of the specifics of biodiversity policy has been unsatisfactory partly because of the different meanings of the word "value" used by economists and ecologists. Many ecologists fail to understand the logic of market allocation and why biological resources are used in seemingly irrational ways. Many economists fail to appreciate the narrowness of the concept of economic value as indicated by relative prices determined by market exchange. Following Anderson (1966) and Brown (1984), the discussion below considers economic measures of value to be species of the genus *assigned value* which belongs to the family *value*.

Many biologists and paleontologists believe that we are at a critical point in the history of the human species, and perhaps even in the 600-million-year history of complex multicelled life on earth. If the paleontologists and biologists who study the phenomenon of mass extinction are correct, the current human-induced mass extinction may be of the same order of magnitude as the five other major extinction episodes which destroyed between 20 and 96 percent of existing species on the planet (Ehrlich and Ehrlich 1992; Ward 1994; Wilson 1992). We are living in a truly remarkable period in Earth's $4\frac{1}{2}$-billion-year history. The valuation decisions our species has made in the recent past and will make during the next few decades will determine the fate of life on Earth for the next tens of millions of years. It is critical to clarify the language and concepts we use to estimate the value of biodiversity, and thus policies leading to its destruction or preservation.

The importance attached to the issue of biodiversity preservation necessarily involves ethical judgments about duty to future generations and responsibility toward the nonhuman natural world. Although individuals hold a variety of conflicting beliefs about human responsibility to the natural world, this does not mean that policy choices

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[1] The term biodiversity encompasses all of the species that currently exist on Earth, the variations that exist within each species, and all of the interactions that exist among all of these organisms and their biotic and abiotic environments as well as the integrity of these interactions.

[2] In one of the most thorough surveys to date, Pimm et al. (1995) estimate that current extinction rates are 100 to 1,000 times higher than their pre-human levels. This rate is expected to increase tenfold in the next century. Economist Julian Simon's (in Meyer and Simon 1994) claim that there has been no increase in extinction rates is "not scientifically credible" (Pimm et al. 1995, 348).

about biodiversity projection can or should be divorced from ethical considerations. Advocating economic efficiency as the prime policy criteria is itself an ethical judgment. Arguments for preserving biodiversity necessarily move through a hierarchy of economic and ethical considerations, from immediate economic self-interest, to possible self-interest (risk avoidance), to responsibility toward the future (Bingham et al. 1995).

As discussed below and elsewhere (Gowdy 1994, 1996; Gowdy and McDaniel 1995), there are fundamental conflicts between the rules by which markets allocate resources and the rules which govern ecosystems. The question is how, when, and in what form will these conflicts be resolved. Although our present socioeconomic system cannot continue to expand indefinitely by destroying biodiversity, it is quite possible that economic growth can continue for decades or perhaps even centuries. That is the essential point in a provocative article by Sagoff (1995).[3] If biodiversity loss and all the other forms of environmental degradation will not appreciably affect economic activity in the immediate or even medium-term future, why should we bother protecting it? The thrust of Sagoff's argument is that ecologically minded economists need to address this question directly, and the remainder of this paper is devoted to that task.

## II. MARKETS AND BIODIVERSITY

Contemporary microeconomic theory is a theory of allocation. Market-based values are at bottom trade-off ratios (Freeman 1991). Microeconomic theory explains the rules by which markets allocate goods and services among consumers, and productive inputs among producers. For consumers, for any given amount and any given distribution of goods, and assuming that (1) participants in the market have all the relevant information about the objects exchanged in markets, (2) each participant buys or sells a very small portion of the total amount being traded, and (3) there are no barriers to entering and leaving the market for any particular good, unhindered market exchange will result in Pareto optimality; a situation in which no further trading can make one person better of without making someone else worse off. In a real or hypothetical market framework, the value of biodiversity is determined by adding up the market prices times the quantities traded of all the various attributes of biodiversity. Marshallian measures of consumer surplus may be adjusted according to the suggestion of Hicks, taking into account changes in real income as prices go up or down (Hanley and Spash 1993; Mitchell and Carson 1989, 24–30).

Neoclassical economists recognize market imperfections and know that prevailing market prices may not reflect the true value of a particular good. They have developed sophisticated techniques such as contingent valuation and hedonic pricing to capture economic values which are not fully reflected in market prices (Cummings, Brookshire, and Schultze 1986; Hanley and Spash 1993; Mitchell and Carson 1989). The theoretical validity of these widely used valuation methods depends directly on the validity of the indifference curve analysis of the neoclassical model of exchange (Freeman 1991). Economists recognize that externalities might exist, that information may be imperfect, and that markets may not be fully competitive. Many economists, however, fail to recognize the limitations of basing values entirely on the preferences of isolated individuals acting as consumers at a specific point in time, although others, such as Sen (1967) and Marglin (1963), have noted the difference between decision making in a private market context and a social (citizen) context.

[3] Sagoff overstates the case for the ability of markets to overcome resource scarcity. Among other things, he equates a declining resource use per unit of output with declining absolute use, ignores Georgescu-Roegen's subtle distinctions between stocks and funds, relies on Solow's outdated and no longer accepted analysis claiming that pure technological change is responsible for most economic growth, and unquestioningly accepts the neoclassical concept of weak sustainability. Sagoff's optimistic conclusions also rely on markets and technologies which, over time, erode the moral and social basis for further progress (Homer-Dixon 1995). See Daly (1995) for a brief reply to Sagoff's article.

The preferred neoclassical method for estimating the nonmarket values of environmental attributes, contingent valuation, actually captures a hodgepodge of market values and broader values and forces them into the indifference curve framework of market exchange. Moreover, the convention of using willingness-to-pay over willingness-to-accept measures has no coherent theoretical justification, and results in an undervaluation of environmental features (Bromley 1995). Difficulties with establishing total value based on market determined prices include (1) discounting the future (Arrow et al. 1995; Bishop 1992; Price 1993), (2) the incongruity problem, that is, reducing all the complex attributes of something to a single, one-dimensional metric (utility or money) (Georgescu-Roegen 1954; Vatn and Bromley 1994), and (3) the existence of pure uncertainty (Bishop 1978, 1979; Bromley 1989; Ciriacy-Wantrup 1968; Gowdy and McDaniel 1995).

Biologists such as Ehrenfield (1988), Ehrlich and Ehrlich (1992), and Wilson (1992) argue that biodiversity has values that are difficult or impossible to measure in market prices. Ecosystems are complex, indivisible entities which operate on timescales outside the range of individual human experience or perception. For example, the health of some forest ecosystems depends on periodic fires that may occur only once in several decades. Short-term ecosystem instability may be an essential part of long-term stability (Pimm 1991). Wildlife managers are beginning to incorporate natural levels of change into planning policies (Pickett, Parker, and Fiedler 1992). Ecosystems may also be seen as hierarchical layers of processes operating at different levels of complexity, each level operating on vastly different spatial and time scales (O'Neill et al. 1986).

For many biologists, the total value of biodiversity is essentially infinite; it is essential to the sustainability of life on Earth including human life. Ehrlich and Ehrlich (1992, 225) write:

> The ravaging of biodiversity, in our view, is the most serious single environmental peril facing civilization. Biodiversity is a resource for which there is absolutely no substitute; its loss is irreversible on any timescale of interest to society.

To most economists, even to most environmental economists, biodiversity is just another commodity, subject to trade-offs and substitution at the margin, just as any other market good. Solow (1993, 181) writes:

> [H]istory tells us an important fact, namely, that goods and services can be substituted for one another. If you don't eat one species of fish, you can eat another species of fish. Resources are, to use a favorite word of economists, fungible in a certain sense. They can take the place of each other. That is extremely important because it suggests that we do not owe to the future any particular thing. There is no specific object that the goal of sustainability, the obligation of sustainability, requires us to leave untouched .... Sustainability doesn't require that any *particular* species of fish or any *particular* tract of forest be preserved. (Italics in original.)

Solow, like most neoclassical economists, does not recognize that species are unique, or that if particular species or ecosystems are "traded" for monetary gain they cannot be replaced. In the standard economic view "utility" derived from enjoying a rainforest is the same as "utility" derived from the sale of lumber from clear-cutting and destroying that rainforest. The value of anything can be expressed in some common denominator, "utils" or whatever, and one util is as good as another. Casting the argument in terms of marginal utility or marginal value does not resolve the issue. Marginal value is the change in total value; if we cannot estimate total value we cannot estimate marginal value.[4] Furthermore, when we talk about ecosystems, the concept of the

[4] Some may object that we only need to rank utilities (and thus values if we make the assumption that utility is measured in the value of actual or contingent consumer goods) not measure them cardinally. This issue has not been resolved in spite of the universal adoption of ordinal ranking in almost every microeconomic text. Georgescu-Roegen (1968) points out that diminishing marginal utility has no meaning without some notion of cardinality. He argues that we need at least *weak cardinality*, that is, we need to be able to not only rank commodity bundles but also to rank the differences between them.

marginal value of biodiversity is problematic. Removing one species will affect all the others in the system. Environmental features are characterized by "functional transparency" (Vatn and Bromley 1994), that is, contribution of one feature of an ecosystem cannot be known until that feature is absent. As discussed below, the fact that precise marginal values cannot be placed on biodiversity does not mean that substitution and trade-offs are not relevant to public policy regarding biodiversity protection. If, however, policy choices are restricted to market trade-offs, higher-order aspects of biodiversity value will be missed.

A useful exercise to examine the conflicting views of the value of biodiversity is to consider the value of biodiversity at different levels in a hierarchical framework, beginning with value in market exchange, through total economically calculable value and total potential value to humans (including uncertainty and the need for precaution), to its value to the stability of the entire biogeophysical configuration of planet Earth. Such an exercise shows the danger of basing biodiversity protection policy on the narrow criterion of value in market exchange.

## III. THE MARKET VALUE OF BIODIVERSITY

Market value is the value of a commodity relative to other market commodities available to individual consumers at a specific point in time (Gowdy 1996; Price 1993). The determination of value through the process of exchange is eloquently described by neoclassical microeconomic theory.[5] Numerous studies have estimated the value of biodiversity in the context of market exchange. Specific case studies show that biodiversity can have a substantial market value. The following examples are by no means exhaustive and are reported only to show the range of market values provided by biodiversity and the various ways economists have attempted to capture these market values.

### *The Commercial Value of Biological Resources as Raw Material*

Peters, Gentry, and Mendelson (1989) estimated that the economic value of a hectare of forest in Mishana, Rio Nanay, in the Peruvian Amazon, based on the yield of various forest products (12 products) was $422 per year after deducting transport costs and harvesting cost. The value of timber on delivery to the sawmill was $1,000. Using a discount rate of 5 percent they estimated the net present value of the sustainable harvest at $6,330 per hectare.[6] A frequently cited example of the value of natural products is the rosy periwinkle (*Catharanthus roseus*) of Madagascar which produces two alkaloids that have been used to manufacture drugs that cure Hodgkin's disease and lymphocytic leukemia. The income from the sale of these drugs is estimated to be more than $180 million per year (Wilson 1992, 283). Many plants, for example, the alpine pennycress (*Thlaspi caerulescens*), have been used to remove toxic metals from contaminated soils. Tropical plants seem to be particularly adept at removing toxic metals, possibly because metal accumulation is a defense against harmful insects and microbes (Moffat 1995). It is even possible to

[5] Neoclassical economics does an excellent job of explaining exactly how consumers make market choices. As Bishop (1992) points out, the problem is that neoclassical economists have been lazy in exploring the implications of their analysis of market exchange. As illustrated by the downward sloping indifference curve, markets essentially force all goods to be substitutes. Every introductory text, of course, discusses complementarity, such as that between tennis balls and tennis rackets. Using appropriate techniques testing for separability, these goods can be lumped together as one good, which can be tossed back into the market world of substitutes.

[6] This assumes that 25 percent of the crop is left intact for regeneration ($316.5/.05 = $6,330). At a discount rate higher than 31.6 percent the economically rational decision would be to cut down the trees. Such a discount rate may seem very high but may not be unusual for poor people in the Amazon basin. There are probably additional costs involved in participating in 12 separate markets for forest products as opposed to participating in a single well-established market for lumber. See the extensive discussion of the value of natural products in Oldfield (1988).

burn the plants and then recover valuable metals such as copper and nickel.

A well-known example of the value of preserving biodiversity is the agreement between the Merck & Co. Inc. and Instituto Nacional de Bioversidad de Costa Rica (INBio). Merck has agreed to pay INBio $1 million over two years for the right to prospect for commercially valuable biological material in plants, insects, and soils (Gershon 1992). So far, results have been disappointing for Merck and the INBio contract may not be renewed when it runs out in 1996. Critics of the INBio agreement point out that many of the rainforest products in Costa Rica are also found in neighboring countries which will not share the proceeds of the agreement and that without further conservation policies the Merck agreement will do little to halt biodiversity loss (Martinez-Alier 1994).

In general, it must be said that the total market value of drugs from tropical forests is not overwhelmingly high. Mendelsohn and Balick (1995) estimated the potential value of all yet-to-be discovered rainforest drugs to be between $3 and $4 billion to a private pharmaceutical company and $147 billion to society as a whole, figures far below previous estimates because they (correctly) used net revenues instead of gross revenues to calculate market value. Their net revenue calculations took into account the costs of research and development, taxes, manufacturing, and marketing. Of course, market value is only one part of total value of biodiversity and the fact that the market value of drugs from plants is relatively small does not mean that this contribution of biodiversity is unimportant to medical research. A letter to the journal *Science* (Torrence 1995) representing 138 biomedical research scientists makes this point: "We believe that the progress of biomedical research and disease treatment depends on the maintenance of the greatest possible diversity in nature."

### *Ecotourism*

There are very large direct and indirect economic values of nature through ecotourism. Part of the value of ecotourism arises from geological features such as the Grand Canyon, but much of it is due to biodiversity. Geist (1994) estimates that the direct economic benefit of Wyoming's big game animals, from tourism and hunting is about $1 billion or about $1,000 per large animal. He estimates that the total economic benefit resulting from the protection of wildlife in all North American national parks for tourism is more than $70 billion. In a study of the Greater Yellowstone area, Power (1991) found that recreation, not mining, timber and ranching, is by far the largest generator of income and jobs. Power concluded that not only is preservation of the ecological and biodiversity integrity of the Greater Yellowstone area not in conflict with local economic well-being, it is in fact essential to it.

Costa Rica has been one of the most successful promoters of ecotourism. More than 7 percent of Costa Rica's tourism income comes from ecotourism. In spite of efforts to protect the remaining natural areas, population pressure continues to threaten the integrity of the public and private reserves in Costa Rica and there are few corridors connecting them. The size of existing reserves is too small to support large species such as jaguars. As shown in the economic data for the Greater Yellowstone area, income from recreational use can justify preserving natural areas and biodiversity. In the process, it can also create an economic and political lobby against extractive uses such as mining and logging. There are also potential conflicts between ecotourism and biodiversity preservation. Close contact with some species may interfere with animal behavior patterns. Most areas set aside for ecotourism are rather small, fragmented and vulnerable, a problem acutely illustrated by the plight of the mountain gorillas caught in the civil strife in Rwanda. There are also frequent conflicts between local residents and tourists, particularly in Third World countries.

### *Ranching and Farming of Wild Species*

Ranching and farming of wild species has also been advocated as a way to translate their preservation into market value. Ranches are dependent upon turtle eggs taken from the wild and farms are completely self-contained and use eggs from their own breeding turtles. Ranching of Green Iguanas and Pacas (a large nocturnal rodent related to guinea pigs) has been tried with some success in Central America (Ocana et al. 1988). An economically intractable problem is the low growth rate of many species. In a study of Dugong (Manatees) and Green Turtles, two species hunted for their meat, Tisdell (1986) found that the rapidly maturing turtles are profitable to farm, but such a strategy is not economically feasible for the slow-to-mature Dugong. Dugong do not reach sexual maturity until age 9–10 years, pregnancy rates are very low, and the interval between births is from three to six years. Dugong are a beautiful and peaceful species but the existence of pure time preference, expressed in a high and positive discount rate, makes them uneconomical to preserve.

Farming and ranching may damage vulnerable ecosystems, for example, by displacing other competing species or overgrazing by the animals being farmed. However, it might be the lesser of two evils in tropical forests. Even severely damaged ecosystems might eventually repair themselves if all the pieces are still present. Once species are extinct, they will never return. Farming may be the only alternative to extinction in many cases.

There is little doubt that specific natural products can have great value. However, market-based arguments for the value of biodiversity in general are more problematic. Although there are certainly large direct market benefits from exploiting biodiversity, it should be recognized that these values are a very small part of the world's economic national product, that many of the potential economic uses of biodiversity depend upon tenuous and risky markets, and that many of the proposals to exploit specific species may cause great damage to fragile tropical ecosystems. Those who rush to praise markets as the great protector of biodiversity should remember that one of the greatest "contributions" of wildlife to economic profit is the illegal trade in endangered species. The international trade in wildlife goods such as Siberian tiger parts, rhino horns, and elephant tusks may amount to as much as $5 billion to $8 billion a year (Associated Press 1994).

Many attributes of biodiversity have real and sometimes very high market values. It is, however, quite possible that basing biodiversity preservation decisions on market values could result in their destruction for economic gain. The very narrow and ephemeral framework of the market-based valuation of biodiversity should be explicitly recognized. Much of the neoclassical theory that was developed to analyze the static exchange of a fixed amount of reproducible goods is inappropriate as a basis to formulate policies to allocate irreproducible and absolutely essential biological entities. This point is implicitly recognized by every human society, including our own, which have elaborate and well-defined rules of behavior to protect the greater good from the whims of isolated individual self-interest. Vatn and Bromley (1994), Douglas and Wildavsky (1982), Kneese and Schultze (1985), among many others, discuss how narrowing the range of possible choices can distort perceptions of value.

The neoclassical explanation of biodiversity loss is succinctly stated by Herb Gintis[7]:

> The price of biological diversity is zero because of a market failure (there is no market in biodiversity). Therefore people will use as much as they please of it in the service of other ends (e.g., profit). Therefore it will be used up more rapidly than socially desirable.

This is a good statement of the neoclassical position and it lays bare the narrow conception of value of neoclassical economics and of the market economy neoclassical theory describes. Among the assumptions implicit in this quotation are the following, (1) a meaningful price can be put on biodiversity,

[7] This quote is from an e-mail response to Alan McGowen in the ecological economics forum, August 9, 1994.

(2) biodiversity is substitutable market good just like any other, and (3) it is socially desirable to use up biodiversity (albeit at a slower rate than the present one) in the pursuit of market goals. What are the limitations of this characterization of value and how may we categorize values at levels in the hierarchy above market exchange?

## IV. THE TOTAL VALUE OF BIODIVERSITY TO THE HUMAN SPECIES

In the 19th century historian Thomas Arnold referred to economics as "the one-eyed" endeavor and according to Georgescu-Roegen (1984, 21):

> It is a judicious characterization because it has retained its currency ever since. Standard economists . . . have indeed refused to see that economic value extends beyond the market mechanism.

An example by Sagoff (1988) illustrates the difference between market values and the total value people place on the natural world. In the late 1960s Walt Disney Enterprises proposed to develop a ski resort in the Mineral King valley in Sequoia National Park in California. Sagoff, in an informal survey of his students, found a striking difference between the choices people make as consumers and the choices they make as citizens. Very few students expressed a willingness to visit the area if it remained a wilderness; the vast majority indicated a strong interest in visiting Mineral King if it were developed as a ski resort. Would these students choose to develop the area if the choice were up to them?

> The response was nearly unanimous. The students believed that the Disney plan was loathsome and despicable, that the Forest Service had violated a public trust by approving it, and that the values for which we stand as a nation compel us to preserve the little wilderness we have for its own sake and as a heritage for future generations. On these ethical and cultural grounds, and in spite of their consumer preferences, the students opposed the Disney plan to develop Mineral King. (Sagoff 1988, 51)

This example calls into question a basic tenet of welfare economics, that it is possible to construct a social welfare function based on a ranking of individual utility functions as revealed by consumer choices. Economists usually avoid dealing with the philosophical difficulties involved in the distinction between the choices people make as consumers and as citizens. The approach of Varian (1992, 333) is typical:

> The most reasonable interpretation of such a [social welfare] function is that it represents a social decision maker's preferences about how to trade off the utilities of different individuals. We will refrain from making philosophical comments here and just postulate that some such function exists.

Neoclassical economists argue that they are taking the ethical high ground by asserting that individual preferences are sacrosanct. Randall (1988, 217) writes:

> The mainstream economic approach is doggedly nonjudgmental about people's preferences: what the individual wants is presumed to be good for that individual.

The problem is, as the Mineral King case illustrates, that what is good for the individual as indicated by market signals is frequently an inadequate reflection of individual choice as indicated in a more universal (and more realistic) context. The neoclassical social preference function is based only on individual choices made in markets. And, it should be added, these individual choices are assumed to have no adverse effect on other individuals, there is no "impossibility theorem" (Arrow 1951) to contend with, and no collective good apart from that revealed by the sum of market-based, self-interested-individual utilities.

The basic argument here is a simple one made by many other economists and political theorists, namely, that individual preferences cannot be fully expressed in the narrow realm of market exchange (see Daly and Cobb 1989; Elster 1983; Marglin 1963; Mishan 1980; Sen 1977; Sagoff 1988). In the case of biodiversity loss we are clearly confronted with absolute scarcity and irrevocable loss; a loss which may affect the long-run survival of our species. This represents a new problem of valuation and one in which the valuation methodology used cannot pretend to be independent of ethical judgments (Funtowicz and Ravetz 1994, 198).

Economists attempt to capture nonmarket values by invoking the concepts of option, existence, and bequest values to individuals. Option value is the price an individual would be willing to pay to preserve something for future use. Existence value reflects the utility to an individual of preserving something for its own sake whether or not it is used in the future. Bequest values reflect the utility gained from leaving something of value to future generations. Forcing bequest, option, and existence values into a market choice framework ignores the intractable conflicts between market-constrained choice and citizen valuation. The result is a neither fish-nor-fowl mix of the two. Private decisions about available market choices cannot capture collective choices.

Many mainstream economists who recognize the limits of markets to reveal the value of biodiversity argue that an expanded cost-benefit framework can capture all relevant values. Randall (1988, 219) writes:

> Most issues involved with biodiversity violate the special case where market price is a valid indicator of economic value. Nevertheless, the general theory of economic value encompasses these broader concerns.

Other economists argue that attempts to expand the scope of market valuation through techniques such as the contingent valuation method (CVM) "contribute minimally—if at all—to the relevation of values" (Vatn and Bromley 1994, 130). The expressed purpose of CVM is to take "public goods" and put them in a hypothetical market context where they can be evaluated in an indifference curve framework in order to establish a "price" relative to goods traded in the market. Such a method confuses social and private choices. As the Mineral King example illustrates, there is ample evidence that these kinds of choices are different.

The response of many neoclassical economists is to criticize hypothetical surveys for not requiring actual monetary payment. The standard economic view is that any values other than those expressed through market payments are not "real." Neill et al. (1994) criticize open-ended hypothetical surveys for not accurately eliciting "real economic commitments." The thrust of their paper is that any commitment not expressed in terms of market exchange is not "truthful." This view is expressed clearly by Branden, Kolstad, and Miltz (1991, 12):

> Many economists are loath to base economic values—values that will be used to allocate real resources—on information that does not grow out of real economic commitments.

By this view, nonmarket decisions about the value of something, which are not made in the everything-is-substitutable, everything-has-a-price world of neoclassical theory are not "real." In fact, a study by Spash and Hanley (1995) found that valuation methods which elicit bids for biodiversity preservation fail as measures of welfare changes due to the prevalence of lexicographic preferences.[8] In lexicographic cases individuals are unwilling to make trades; one thing is absolutely preferred over another. They found that a significant number of respondents refuse to make trade-offs between biodiversity and market goods. They also found that knowledge about biodiversity and its importance is extremely limited. Both findings call into question the very basis of cost-benefit calculations. In a CVM study estimating the value of four wildlife species in New England (bald eagle, Atlantic salmon, wild turkey, and coyote) Stevens et al. (1991) found evidence for lexicographic preference ordering. Forty-four percent of all respon-

[8]The problem of lexicographic ordering of preferences was raised decades ago by Georgescu-Roegen (1936, 1954). The relevance of his early work in utility theory to environmental economics has been neglected not only by neoclassical economists but also by those sympathetic to his later work about the entropy law and the economic process.

dents agreed with the statement that "preservation of wildlife should not be determined by how much money can be spent." Sixty-seven percent of all respondents agreed with the statement that "As much wildlife as possible should be preserved no matter what the cost." Stevens et al. (1991, 398–99) write:

> A more fundamental issue concerns whether or not respondents made meaningful tradeoffs, and our results suggest that the majority of respondents who were willing to pay used decision-making processes inconsistent with the neoclassical paradigm of tradeoffs between money and wildlife.

Panel study results reported by Stevens, More, and Glass (1994) and by Kahneman and Knetsch (1992) suggest that contingent valuation questions may be capturing things like moral satisfaction and feelings of civic duty to contribute to a worthy cause. Neoclassical economists call this the "embedding effect" and they have devised elaborate techniques to isolate this aberration from standard theory.

An intractable conflict between markets and ecosystems is the necessity for discounting monetary values. The incompatibility between the pure time preference of individuals making decisions at a point in time and the social value of environmental sustainability has been widely discussed and will not be explored in depth here (see Price 1993). Amin (1992, 525) puts it succinctly:

> The practice of discounting the future appears to be an obvious psychological law. However, one cannot extend such discounting to society at large, in any sphere . . . because with a rate of only 4% over 30 years, any value is reduced to two-thirds of its initial value, leaving a margin of almost absolute uncertainty about the validity of choices. But if 30 years can appear a respectable period in the scale of human life, what does it represent in the time frame of the history of nations and of humanity?

Many mainstream economists recognize the discounting problem but fail to come to grips with its intractability in standard economic valuation. Randall (1988, 219–20) correctly points out that discounting could justify the complete collapse of living systems in only a few hundred years from now if it is offset by minor economic gains in the present. Yet he asserts that there is an "almost adequate conceptual basis for economic valuation of biodiversity"; the "almost" referring to the discounting problem.

Another value of biodiversity that transcends market value is called the "biophilia hypothesis" (Wilson 1984). According to this hypothesis, humans are fundamentally complex mammals that seek variety and new stimuli in the context of the biological world. Some regular contact with nature and other species is essential to human mental health and well-being. Although the study of biophilia as a scientific concept is only in its infancy, some research has attempted to test the hypothesis. Ulrich (1993) discusses a number of studies that found a positive relationship between measures of emotional well-being and natural (non-built) environments. According to him, "this aesthetic appreciation for nature may be universally expressed across human cultures" (Ulrich 1993, 49). For example, a study by Yi (1992) comparing Texans and Koreans, found that positive feelings about specific types of landscapes were not culturally specific; urban dwellers and farmers from both cultures responded positively to the same types of natural objects and settings. To the extent that biophilia is not reflected in market values, or is even thwarted by economic activity, this reflects another aspect of biodiversity above and beyond that captured by market or pseudo-market valuation. Orr (1994, 149) writes:

> Biophilia can be suffocated, for example, by the demands of an economy oriented toward accumulation, speed, sensation, and death. But economists have not written much about how an economy encourages or discourages love generally or biophilia in particular.

Biophilia may be part of the reason for the lexicographic ordering of preferences for environmental protection that regularly show up in CVM surveys. Biodiversity may be an essential, non-substitutable, factor for the psychological well-being of humans. It may be part of a hierarchy of essential needs along with food, shelter, sex, and companionship necessary for the enjoyment of life. Some of the founders of modern utility theory (Georgescu-Roegen 1936, 1950; Menger 1950) argued for a hierarchical representation of human needs. Georgescu-Roegen (1968, 263) argued that it is the principle of the irreducibility of wants, not the postulate of indifference, that should be at the base of a realistic theory of choice. If the biophilia hypothesis proves to be true, it could provide the strongest argument of all for the preservation of biodiversity. Biodiversity may not be just another item in the consumer's utility array. It may be essential for our psychological well-being.

Recent theories of social conflict suggest yet another value of biodiversity not captured in market prices. Dasgupta (1995), drawing on empirical studies from a number of disciplines, finds self-reinforcing links between population growth, poverty, and the degradation of local environments including biodiversity loss. A comprehensive study by Homer-Dixon, Boutwell, and Rathjens (1993) concludes that increasing natural resource scarcity can strengthen the hand of the social elite and exacerbate an unequal distribution of resources. The loss of wild biodiversity in agricultural systems can contribute to increased vulnerability and increase the likelihood of social instability (Gowdy 1997). The role that biodiversity plays in maintaining social order is another positive "value," and another attribute that is impossible to measure.

The apparent positive relationship between social stability and natural resource preservation raises fundamental questions about individual choices, democracy, and the social contract. Should policies to protect biodiversity be based upon some democratic representation of the preferences of humans? This is an extremely difficult philosophical problem. One might argue that all choices are necessarily based on individual preferences. The context of these preferences, however, makes a difference (Bromley 1990, 1991; Sagoff 1994; Vatn and Bromley 1994). In the next valuation section below, describing the ecosystem value of biodiversity, an essential point is that there is a real world outside the human mind.[9] Our preferences can be whatever we choose, but if our choices, individual, social or otherwise, are not consistent with biophysical reality, our complex technological culture and perhaps our species will join those other cultures and species that have become extinct. Humans have negative feelings about organisms which are essential parts of ecosystems. Many unappreciated groups of organisms, such as the insects, algae and fungi, are essential for the existence of other forms of life, including humans. Yet these organisms rank low in esteem for humans and there is little chance of improvement in their image (Kellert 1993). Choices based on human preferences, no matter how broadly defined, are bound to undervalue the importance of preserving these creatures. Vatn and Bromley (1994, 138):

> It seems as if some have come to regard the natural environment as a large zoological garden from which we can select for policy attention those parts that happen to hold our momentary affection. But first we have to value it to reassure ourselves that the attention is warranted, or that the attention is efficient.

Ecosystems obey some basic rules that have been established over the $3\frac{1}{2}$-billion-year history of life on planet Earth. The highest hierarchy of the value of biodiversity is its value in stabilizing the life support system which makes human existence possible.

## V. THE ECOSYSTEM VALUE OF BIODIVERSITY

For many decades ecologists has suspected that biodiversity plays a positive role in the health of ecosystems. However, until very recently there has been no direct ex-

[9] Some economists argue otherwise. According to Gilder (1981): "Because economies are governed by thought, they reflect not the laws of matter but the laws of the mind." Simon would have us believe that "in the end, copper and oil come out of our minds" (quoted in Daly 1985). For a peculiar mix of radical environmentalism and neoclassical technological utopianism see Sagoff (1995).

perimental evidence for this positive role. Tilman and Downing (1994) found that biodiversity plays a crucial role in maintaining the resilience of ecosystems to environmental shocks. In a study of Minnesota grasslands they found that primary productivity in more diverse plant communities is more resistant to drought and recovers faster.[10] Alarmingly, in view of the predicted sharp increase in extinction rates, they found that each additional species lost in the grasslands they studied had an increasingly greater negative impact on drought resistance. In another controlled experiment Naeem et al. (1994) also found that declining biodiversity adversely affected the performance of ecosystems in terms of plant productivity, nutrient retention, water retention, and decomposition. Tilman et al. (1994) argue that, primarily because of habitat fragmentation, the stage is set for a sharp increase in extinction rates in the near future. They write:

> Even moderate habitat destruction is predicted to cause time-delayed but deterministic extinction of the dominant competitor in remnant patches. Further species are predicted to become extinct, in order from the best to the poorest competitors as habitat destruction increases. Moreover, the more fragmented a habitat already is, the greater is the number of extinctions caused by added destruction. Because such extinctions occur generations after fragmentation, they represent a debt—a future ecological cost of current habitat destruction. (Tilman et al. 1994, 65)

Perhaps the most important ecological value of diverse ecosystems is the preservation of evolutionary potential. Species diversity, as well as genetic diversity within species, allows species and ecosystems to adapt to environmental changes. Natural systems are not in a "state of equilibrium" as economists use the term equilibrium. Economic theory refers to an equilibrium system as one which returns to its initial state after a disturbance. When ecosystems are disturbed, depending on the nature and extent of the disturbance, they do not necessarily revert to their initial state when the disturbance is removed because the initial state is no longer the same. This flexibility to adapt to different environmental conditions has evolved over eons. Geological records show that the Earth is a constantly changing, even chaotic system. Mountains are formed and eroded, ice sheets expand and contract, and volcanoes disrupt climate patterns. Genetic diversity, as well as higher orders of biological diversity, gives ecosystems the ability to adapt to these changes. When we reduce the variability within the biological world through habitat destruction, ecosystem modification, extinction, and genetic erosion we limit the possible responses to future environmental change. Evolutionary potential has obvious value to ecosystems, but we cannot quantify its value to the human species. There are some examples of evolutionary changes which positively affected human prospects for overcoming adverse changes. Paleolithic human cultures in Europe, whose economies were based on big game hunting, were adversely affected after these animals disappeared with the retreat of the glaciers some 15 thousand years ago. The warmer climate also apparently led to the evolution of certain kinds of plants with larger seeds suitable for agriculture which humans were able to exploit. This kind of evolutionary response depends on nature having a variety of genetic material to work with and illustrates the importance of preserving species *in situ*. We know that human activity is significantly changing climatic conditions on earth at both the local and global levels. With the projected changes in the Earth's biosphere as a result of greenhouse warming (Peters and Lovejoy 1992) we may be destroying the ability of the biosphere to adapt to change at one of those critical

[10] The relationship between ecosystem productivity and diversity is a complicated one. While it is generally true that "diversity begets productivity" it also seems to be true that diversity begins to decline when productivity is very high. Apparently, both high and low levels of productivity are characterized by limitational factors (Tilman 1982, 1986). Robinson et al. (1992) found complex patterns of change resulting from habitat fragmentation. The Tilman and Robinson et al. studies point to the need for detailed population analyses of the specific effects of habitat fragmentation.

times in the Earth's history when adaptability is needed most.

Frequently occurring natural agents such as hurricanes, storms, and fires are essential parts of ecosystem health (Solbrig 1991). Such seemingly destructive events have "value" to ecosystems, but impose large economic costs on human society. For example, the fires on Long Island, New York, during the summer of 1995 caused extensive loss of property but were beneficial to the long-term health of the forest ecosystem. According to Wilson (1992) such events have been "coded for" in the genes of the organisms making up ecosystems. The long-standing policy of fire suppression in national parks and forests is currently being hotly debated and shows clearly the spatial and time scale conflicts between the human economy and ecosystem health.

The total ecosystem value of biodiversity may be the value of the existence of humans and all other species. Norton (1988, 205) puts it nicely:

> The value of biodiversity is the value of everything there is. It is the summed value of all the GNPs of all countries from now until the end of the world. We know that, because our very lives, and our economies are dependent upon biodiversity. If biodiversity is reduced sufficiently, and we do not know the disaster point, there will no longer be any conscious beings. With them go all value—economic and otherwise.

## VI. POLICY IMPLICATIONS

Humans are part of the natural world and any damage humans do to that world has the potential to increase the risk to ourselves. Many economists counter that humans are fundamentally different from other species. We are unique and not subject to the same laws of nature as other species. It is hard to answer this because it is not a testable scientific argument, merely a statement of optimism; "we'll think of something." To counter this argument one can only point to past and present cases where human society did not think of anything clever to save themselves in the face of self-inflicted environmental disaster. There is mounting evidence that almost every civilization since the adoption of agriculture some 10,000 years ago has overshot and collapsed, most of them because of the misuse of their natural resource base. These include the civilization of Easter Island, the Maya, and the Sumerians (Bahn and Flenley 1992; Ponting 1991; Tainter 1988; Weiskel 1989). Easter Islanders degraded the biodiversity of their island by cutting down all the large trees (two species of palm tree and the toromiro) to use as skids for transporting the large statues for which the island is famous. Without these trees, the islanders could not build boats or wooden houses, as they did formerly. Deforestation also caused soil erosion. After the loss of these trees came a precipitous decline in the standard of living for the Easter Islanders (Bahn and Flenley 1992). Likewise, the Maya cut down vast tracts of forest to obtain wood for houses and for firewood to use in heating limestone to produce the white stucco facade for their temples. This deforestation evidently caused soil erosion and contributed to the demise of that civilization (Dobson 1996, 254–55). Of course the cause of the collapse of past civilizations is a complex mix of resource degradation, including biodiversity loss, social instability, and unresponsive political institutions. In view of the history of our species, the argument that humans do not need to conserve biodiversity because we are so resourceful and intelligent seems imprudent at best.

As long as the "ideology of efficiency" (Bromley 1990) continues to dominate the political discussion in the United States and Europe, policy efforts to preserve biodiversity must confront cost-benefit analysis. The thrust of the various arguments presented above is that even if one argues that individual choices are sacrosanct, these choices cannot be fully expressed in the context of market exchange. Economic valuation studies that attempt to capture social values in a hypothetical market situation should be treated with suspicion. If market values, including extended cost-benefit analysis, are not sufficient as a basis for biodiversity protection policy, what should we do? I suggest the following basic considerations.

1. Devising a meaningful single measure, monetary or otherwise, of the value of biodiversity, is impossible. Ecologists have developed numerous indices of different aspects of biodiversity such as species richness and species abundance (Magurran 1988). The consensus among ecologists is that such measures are useful base numbers to show changes within a particular ecosystem but are not comparable across ecosystems. Not everything can be quantified, pure uncertainty is pervasive, and the time-scales involved are beyond the experience of individual humans. We can, however, use a pluralistic methodology (Norgaard 1989) to construct multiple assessments of the various aspects of biodiversity value. As outlined above, a useful procedure is to group the various value concepts according to the following hierarchy. First estimate the present discounted market value of biodiversity, and where appropriate and using various scenarios, reduce uncertainty to risk. Second, estimate the potential nonmonetary value of biodiversity based on decisions humans make as social creatures, not isolated individuals. Finally, use the best scientific information available to assess the function and importance of biodiversity to specific ecosystems and to the long-run viability of the human species. What is the importance of biodiversity to long-run human survival? If we follow Georgescu-Roegen's admonishment "Love thy species as thyself" there is no conflict between biodiversity preservations and the long-run interests of *Homo sapiens*.[11]

2. Incorporate a broad geographic and ecological perspective in policies for biodiversity protection. Five fundamental policy objectives have emerged in the burgeoning literature on ecosystems protection (Noss 1991): (i) In a protected area all native ecosystem types should be represented in their various natural ranges of variation (Pulliam 1995); (ii) all native species in these protected areas should be represented in their natural patterns of abundance and distribution; (iii) ecological and evolutionary processes should be maintained, including everything from predation patterns to hydrological cycles (Holling 1995); (iv) the potential for evolutionary change should be maintained, that is, the response to long-term and short-term disturbances such as fire and long-term climate variation; and (v) the coevolutionary (Norgaard 1984, 1988) relationship between human and natural systems should be explicitly recognized. New federal, state, and nongovernmental organization (NGO) policies are encouraging. The U.S. Department of Interior has officially adopted an ecosystem approach to endangered species management, the State of Florida has made impressive efforts to protect and restore the Everglades based on coevolutionary ecosystem management objectives (Mann 1995), and the Nature Conservancy, in its "Last Great Places" program, has based its land acquisition and management policies on the ecosystem concept.

3. Emphasize biodiversity strategies that broaden the choice set beyond simple cost-benefit calculations. For example, the U.S. Department of Interior is also pioneering the concept of conservation offsets. When a development project is proposed that might threaten an ecologically valuable area, it may be allowed if the developer agrees to restore or expand another threatened area. This kind of ecological swap can be done without calculating economic "values" and

[11] A reviewer raised the question, "Is the case for preserving all biodiversity at the current margin so strong that it should 'trump' all other social objectives?" I do not argue that the value of *any* biodiversity to humans is always infinite. To say, however, that the marginal value of biodiversity is finite, should not be taken to mean that we have an idea about how to measure it. We know the existence of our species depends on other life forms on the planet, therefore its total value is infinite; we cannot continue to destroy it and survive. Furthermore, we have only a vague idea about how the pieces of biodiversity fit together. On the other hand, if we take a broad view of sacrificing biodiversity at the margin, *and* if we have an idea of what an environmentally sustainable society should be, *and* if we are moving toward that, *maybe* we can sacrifice some biodiversity on the way toward that sustainable path. The important point to remember, I think, is that there are limits to the substitutability between "natural capital" and "manufactured capital," and thus limits to the standard economic notion of weak sustainability (see Gowdy and O'Hara 1996).

without quantifying costs and benefits using a common metric. These sorts of policies cannot be undertaken without collective discussion of choices based on some commonly adhered to notion of democratic discourse (O'Hara 1996; Vatn and Bromley 1994).

4. Expand the safe minimum standard (SMS) approach to biodiversity protection to include the preservation of evolutionary potential. The SMS recognizes that species are unique and that the future repercussions of destroying biodiversity are uncertain. This approach, as stated by Ciriacy-Wantrup (1968) and modified by Bishop (1978, 1979) states that the SMS should be adopted unless the "social costs of doing so are unacceptably large" (Bishop 1978, 10). Although Bishop thought of social cost as the cost of preservation borne by current and near-term generations, it should be recognized that reducing the ability of future generations to adapt to new environmental or social conditions is also a social cost of reducing biodiversity. One might argue that we can leave future generations better off by leaving them less biodiversity and more "capital" including scientific and technical knowledge. This argument can be turned around to say that we should leave future generations more biodiversity because they might have developed the scientific and technical knowledge to use species which we now consider to be economically unimportant.

As Vatn and Bromley (1994, 143) point out, the SMS is a fairly crude measure which was developed for decisions involving the critical harvest levels for renewable natural resources. The basis message of the SMS approach is that we should err on the side of caution. In terms of ecosystem exploitation, we should leave them alone if we are not sure of the side effects. With the increasing knowledge of the complexity of evolutionary processes and ecosystems, this leave-it-along strategy should be extended beyond its original formulation to include preserving the evolutionary potential of ecosystems and genetic diversity (Gowdy 1993; Myers 1993).

## VII. CONCLUSION

The problems with the standard economic concept of value as expressed in relative market prices are becoming increasingly clear. Difficulties include problems in cognition, the incongruity problem, indivisibilities and complementarities of ecosystem functions, and pure time preference. Attempts to duplicate market values for environmental attributes through contingent valuation suffer from these same difficulties. It is clear both from theoretical considerations and scientific evidence about the nature of biodiversity, that economists need to broaden their concept of value beyond that determined by market exchange. Such a broader concept of value leads inevitably to the need for a broader array of policy options for the protection of biodiversity beyond those based on simple cost benefit calculations.

The difficulties with the standard economic approach to the valuation of biodiversity raise long-neglected issues in neoclassical utility theory. Fundamental questions were raised decades ago about the meaning of "utility" and were once the subject of a lively debate among leading economists (Georgescu-Roegen 1968). Perhaps a positive spillover effect from the ongoing discussion of "value" among resource economists will be that it will serve as a stimulus to reopen a debate among other economists about the general validity of the concepts of indifference and substitutability which lie at the base of neoclassical theory and policy.

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