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The Economics of Biodiversity

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Environmental Policy

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I) Introduction

Throughout history there has often been a blatant separation between environmental preservation and economic growth, suggesting that the two cannot possibly flourish simultaneously. This idea is not only detrimental to both causes, but prevents their cooperation and coexistence to create a sustainable world. In this paper I will address one of the greatest threats to environmental and economic well-being: the loss of biodiversity. In understanding what biodiversity is and its immeasurable value to society, I hope to exemplify the importance in its preservation. While I will touch on the ecological and ethical reasoning for this, my argument will be mainly rooted in economics. With a brief overview of classical economic theory and its approach to environmental problems, the current flaws with the valuation of biodiversity will be evident. A cost-benefit analysis regarding the protection of biodiversity, though imperfect will support the necessity of preserving worldwide species variation.

While this paper will be specific in addressing the environmental problem of biodiversity loss, I hope the underlying concepts will expose the importance of creating a sustainable future. Through examinations of current environmental policies and the causes of their successes and/or failures, we can stay on track for this goal. Economic incentives for behavioral modification can undoubtedly be the environment's biggest ally in its conservation, if utilized correctly. It is the responsibility of policymakers to implement these incentives to maintain environmental health without harnessing economic growth. When policies are ineffective, as will be discussed, the struggle between environmentalists and economics only intensifies. The loss of biodiversity, as well as the countless other obstacles to sustainability, must be addressed as problems in themselves rather than driving forces of interest group agendas or we will certainly suffer a simultaneous collapse of environmental and economic health.

II) Biodiversity and Human Well Being:

In order to fully understand the economic implications of a loss of biodiversity, we must first understand what biodiversity is and why it is important. The term "biodiversity" refers to the biological variation among organisms within species, populations, and ecosystems (Ecological Society of America, 1). According to the United Nations Convention on Biological Diversity, biodiversity is "The variability among living organisms from all sources, including terrestrial, marine and the ecological complexes of which they are part…" (Convention on Biological Diversity, 1). Biodiversity can be addressed on four levels: gene diversity, species diversity, ecosystem diversity, and functional diversity (Nunes, 9). Because we can view the Earth as one giant comprehensive ecosystem, the loss of any gene/species/ecosystem/functional diversity translates directly to a loss in total biodiversity. Genetic diversity refers to individual DNA structures reflecting unique genetic codes (Nunes, 9). The endangerment status of a species exemplifies this type of diversity. When populations of species decline to the point where they are considered endangered, the unique genetic material circulating within that population has also declined. Therefore, some biodiversity within that population has been lost, which means that total biodiversity on Earth has declined as well. Species diversity is the variety of species on Earth (Nunes, 10). The loss of an entire species through extinction is an obvious loss of biodiversity, and the possibility of such a detrimental event encourages wildlife and habitat conservation.

The last two levels of biodiversity, ecosystem diversity and functional diversity, introduce a reoccurring theme throughout this report, which is the interdependence of Earth's processes. The interdependence between environmental health and economic growth will be later discussed. Ecosystem diversity encompasses both the varying organisms and the communities they inhabit. Studies suggest that ecosystem diversity is related to a limited number of organisms/groups of organisms necessary for the critical processes of its functioning – known as "keystone processes" (Nunes, 11). Without successful functioning of these keystone processes, an individual ecosystem's ability to accommodate an external shock (ex: climate change, human intervention) is hindered. Such an ecosystem becomes less stable and resilient, leading to dramatic changes or eventual destruction to the ecosystem altogether (Nunes, 12). Functional diversity refers to variation in ecosystem functions as a result of interactions between difference structures and processes. Ecosystem structures include its tangible components, such as plants, animals, soil, air and water. Ecosystem processes refer to transformations between systems that provide "life support services," such as maintaining the balance of gases in the air, assimilating pollutants, cycling nutrients, generating and preserving soil, and pollinating crops (Nunes, 12). Interactions between structures and processes that define ecosystem functions reflect ecosystem health. In other words, a healthy ecosystem is a naturally functioning ecosystem. When an ecosystem's structures and/or processes are damaged, its ability to properly function may very well be impaired.

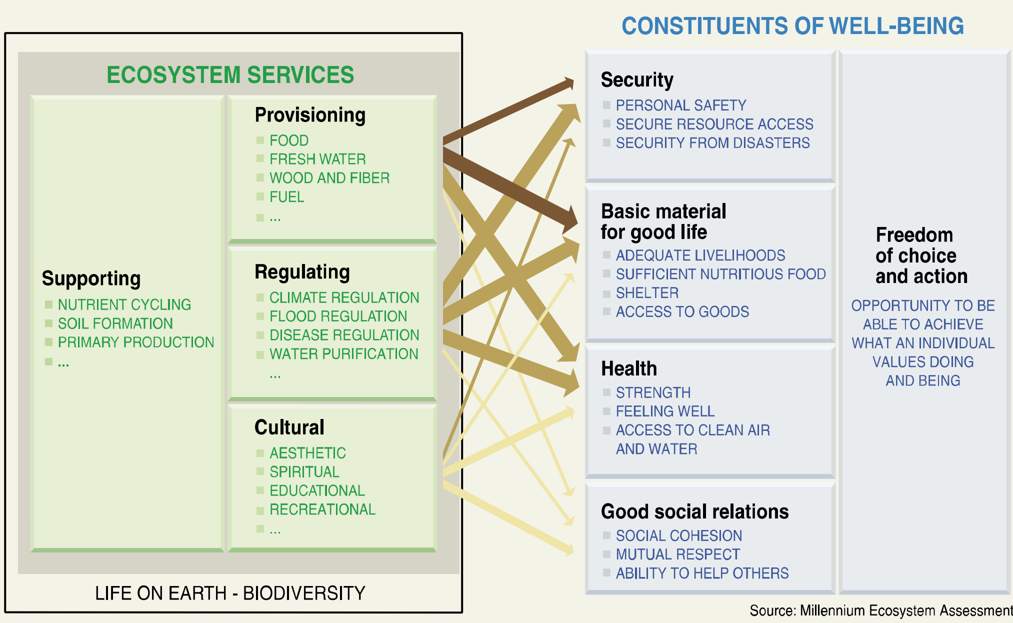
Biodiversity is a complex concept that can be examined at many different levels, as previously discussed. Most important to the understanding of this concept is the understanding of interdependence. Biodiversity is like a machine composed of many simultaneously working parts. When one part is damaged or destroyed, other parts suffer as a result, and the final product may be drastically impaired. Similarly, when we consider biodiversity, we cannot think of all the organisms as separate entities such as composed on a list, but rather we must view such organisms as all interconnected in some way or another in the form of a web. The same can be said of entire ecosystems. In other words, the survival of biodiversity depends on the acceptance and understanding that different ecosystems depend on each other for success. As inhabitants of Earth, mankind is not removed from ecosystem interactions. Rather, we play important roles in their success and vise versa. Therefore, while the loss of a particular species (or introduction of an invasive species) to an otherwise functioning ecosystem may seem unrelated to human well-being, the ripple effects tell a different story. Biodiversity is important to ecosystem functionality, and ecosystem functionality is important to human well being.

The relationship between ecosystems and human well being has been extensively discussed by the Millennium Ecosystems Assessment that was conducted from 2001 to 2005. With regards to what constitutes human well being the Assessment discusses that it includes, "basic material needs for a good life, the experience of freedom, health, personal security, and good social relations" (Millennium Ecosystem Assessment, 73). These five factors can be broken down further which will make the later discussion of their connections to ecosystem services more obvious. Basic materials for a good life include the bare necessities of food, water, shelter, and clothing. These necessities must be continuously provided as the building blocks of complete well being. The experience of freedom refers to the universally desired freedom of choice or the ability to achieve what one specifically values. Health includes both the physical and mental aspects. Personal security refers to secure access to resources, physical safety of person and possessions, and a predictable/controllable environment. Good social relations refer to a positive social environment and relationships between families, friends, coworkers, etc. These factors are greatly intertwined and continuously affect each other both positively and negatively. For example, physical health cannot be achieved without food and water. Food and water cannot be consumed without secure access to these resources. In addition, an unobstructed freedom of choice creates a positive mental health that allows for good social relations.

The interdependence of these factors is reflective of the interdependent relationship between overall human well being and ecosystem services. The Millennium Ecosystem Assessment exemplifies these connections through the following chart:

Figure A. LINKAGES BETWEEN ECOSYSTEM SERVICES AND HUMAN WELL-BEING

This Figure depicts the strength of linkages between categories of ecosystem services and components of human well-being that are commonly encountered, and includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage. (For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation.) The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human well-being depicted here, other factors—including other environmental factors as well as economic, social, technological, and cultural factors—influence human well-being, and ecosystems are in turn affected by changes in human well-being. (See Figure B.)



Source: Millennium Ecosystem Assessment

While some of these services may be obvious to human well being such as the provision of food and fresh water, others are less frequently considered. The importance of all the aforementioned services cannot be stressed enough as their relationships to the factors of human well being are undeniable. There are countless specific examples of how the human population is affected by changes in ecosystem services. Considering the regulating services, specifically disease regulation, ecosystem changes have increased the frequencies and intensities of harmful algal blooms in coastal waters. These toxic blooms can contaminate drinking water and negatively impact human health. It is estimated that half the urban population in Africa, Asia, Latin America, and the Caribbean suffers from a disease associated with unsatisfactory water and sanitation (Millennium Ecosystem Assessment, 12). In addition, ecosystem changes have dramatically increased the frequencies and intensities of floods over the past 50 years. Floods affect approximately 140 million people each year. The resulting forced relocations, deaths, and destruction of property cause staggering physical and emotional damages to entire communities (Millennium Ecosystem Assessment, 53). Specifically considering the relationship between a regulating ecosystem service such as flood control and factors of human well being as exemplified by the chart, changes in flood intensity/frequency destroy personal security by causing people to feel unprotected from natural disasters and unsafe in their homes. This mental health blow can easily deteriorate positive social relations between affected community members. Physical health is in jeopardy as well, as more than 100,000 people were killed in floods between 1990 and 1999 (Millennium Ecosystem Assessment, 53). The physical destruction results in losses of shelters and other basic resources necessary to survival. In addition, natural disasters such as floods limit peoples' freedom of choice to live where they desire. The economic damages increasingly intense and frequent floods have made home ownership in flood prone regions unaffordable, even to the wealthy who could purchase flood insurance (Millennium Ecosystem Assessment, 54).

The connection between ecosystem services and human well being is one that is characterized by complex and extensive interdependence of factors. Because humans are active participants within ecosystems and are greatly affected by them, the relationship is a cyclical one. In other words, humans actively affect ecosystems through utilization of its services (material resources, regulation, and cultural contributions) which affect human well being. In recognizing this relationship, we can more easily stress the importance of maintaining healthy ecosystems to encourage their functional success and our positive well being.

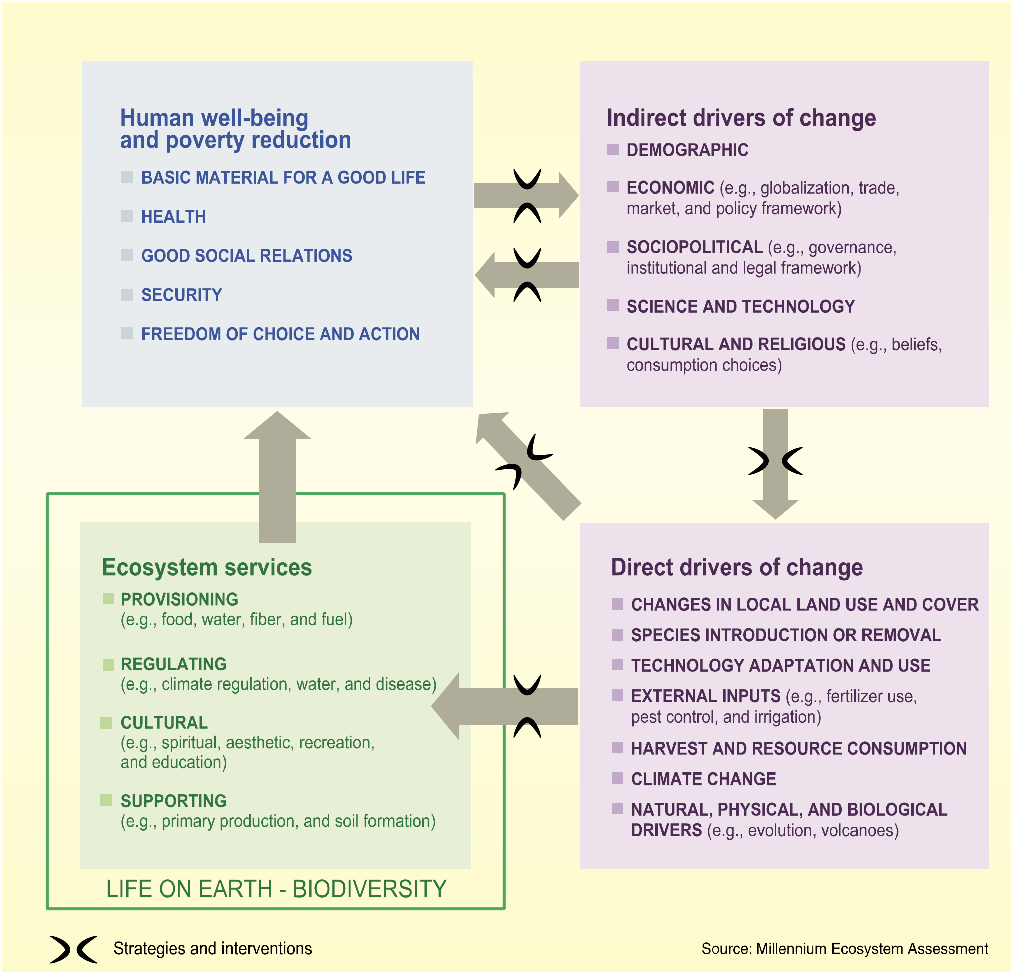
II) Drivers to Biodiversity Loss and Gain

In order to properly address the problem of biodiversity loss, we must understand the drivers of its changing status. The well-established connections between biodiversity and ecosystems, as well as ecosystems and human well being, suggest that there are many factors that could result in such change. These factors can be classified as either direct drivers to change or indirect drivers to change. The Millennium Ecosystem Assessment notes the differences of these drivers through the following explanation,

> A direct driver unequivocally influences ecosystem processes and therefore can be identified and measured to different degrees of accuracy. Indirectly drivers operate more diffusely, from a distance, often by altering one or more direct drivers. An indirect driver can seldom be identified through direction observation of the ecosystem; its influence is established by understanding its effect on a direct driver.

Considering this distinction, a direct driver to an ecosystem change would be the increased use of pesticides in agriculture. An indirect driver would be an increase in consumption choices of consumers which could cause a greater exploitation of natural resources which would have inevitable ecosystem changes. Playing this "extrapolation game" with indirect drivers can easily get messy as it is subject to discretion. In addition, much of the assertions regarding indirect drivers are determined by means of backwards-tracing logic from the result of the drivers. In other words, drivers are identified after an environmental problem has been observed and a connection has been made between that problem and another problem, human action, etc. One falsely assumed connection tracing back a series of indirect drivers could wrongfully identify a problem source and leave the true source unresolved. Another problem is that many ecosystem changes have multiple drivers, both direct and indirect, that contribute to said change. The process of identifying drivers and connecting them to ecosystems changes is obviously quite complex and hindered by uncertainty. Regardless, this process is undoubtedly necessary and important if we hope to disarm the threats to biodiversity and ecosystem functionality.

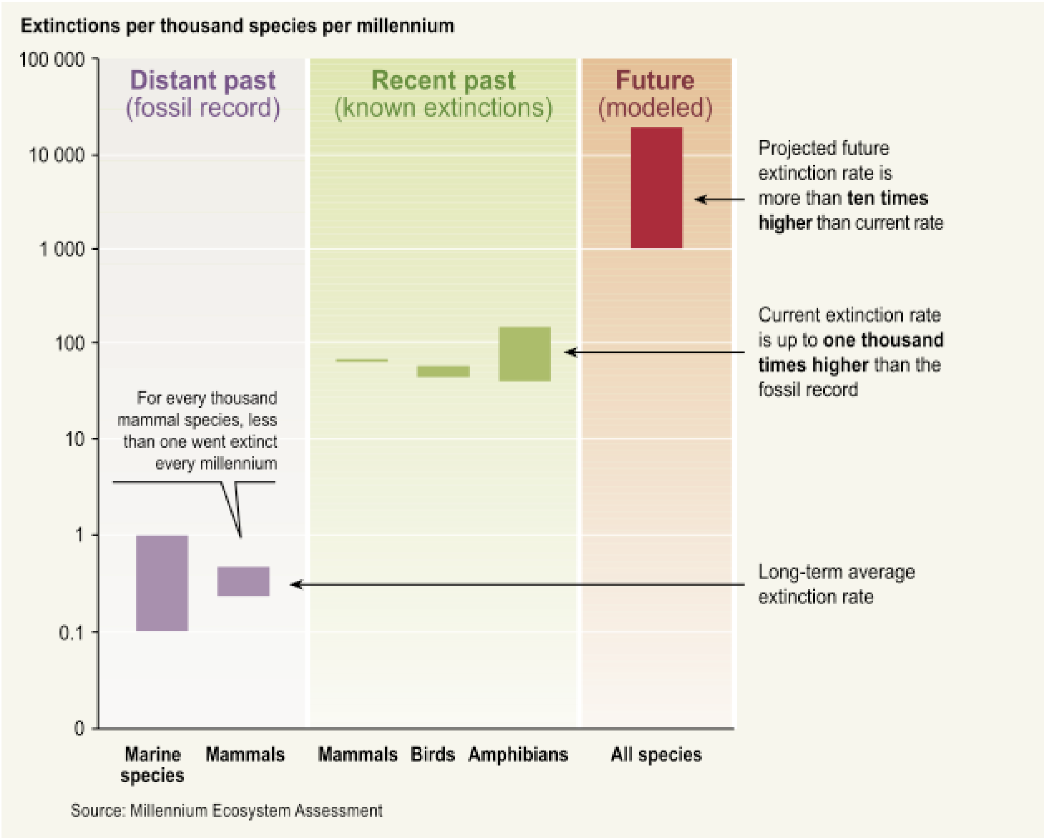
Because all of the direct and indirect drivers of specific ecosystem changes would be impossible to identify and extrapolate, a more understandable and constructive way to consider these drivers is by classifying them more generally. The Millennium Ecosystem Assessment has determined indirect drivers to fall under the following categories: demographic, economic, sociopolitical, science and technology, and culture and religion. Direct drivers of ecosystem changes include changes in local land use and cover, species introduction or removal, technology adaptation and use, external inputs, harvest and resource consumption, climate change, and natural/physical/biological drivers. A flow chart of how these drivers interact with ecosystem services and human well being (both directly and indirectly) is depicted below:



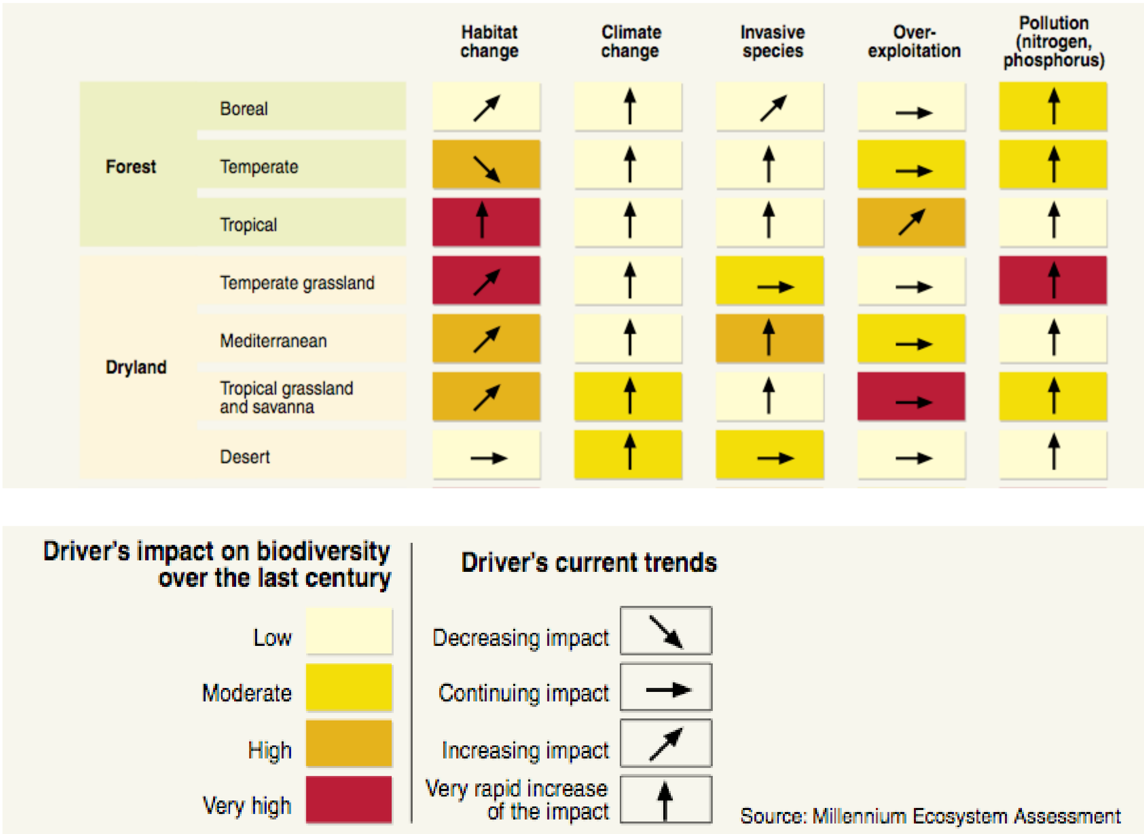
Again, as the chart depicts, we are faced with the recurring theme of interdependence. In accordance with this chart, the Millennium Ecosystem Assessment discusses the concept that "…people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being" (Millennium Ecosystem Assessment, 9). In other words, the constantly changing human condition has direct and indirect effects on ecosystems and their utilization. Changes in human well-being can trigger indirect drivers that can trigger direct drivers that can alter ecosystem services. This in turn affects human well-being again. The cyclical relationship suggests that any one change in human condition has a domino-effect.

The constantly changing "human condition" is defined more thoroughly through the indirect drivers of ecosystem changes. The indirect drivers of demographics, economics, sociopolitical factors, science and technology, and culture/beliefs incorporate an extensive variety of aspects that create the human life experience. Through acquired knowledge and understanding of the various changes ecosystems have undergone, these drivers that are frequently shamed as negatively causing ecosystem changes can be purposefully manipulated to have positive effects. Specifically with regards to biodiversity loss, these drivers are frequently used as arguments in support of different ways the problem should be addressed in an effort to fix it, which will be later discussed.

After a thorough examination of what biodiversity is, how it relates to human well being, and the general drivers behind its changing condition, we can discuss how and why it is being lost. According to the Princeton Guide to Ecology, "Species extinction is, after all, one of the most visible and irreversible manifestations of biodiversity loss, and it remains the subject of much current research" (Causes and Consequences, 23). While species extinctions can and do occur naturally in conjunction with evolution, the extinctions that are currently occurring are directly and indirectly the consequences of human activity. According to the Millennium Ecosystem Assessment, human activity has increased the species extinction rate by as much as 1000 times compared to the planet's historical species extinction rates, as indicated by the following chart:



Human-induced species extinction is primarily the result of changes in land use (ex: habitat destruction), overexploitation, invasive species, disease, and climate change (Causes and Consequences, 23). Habitat destruction is arguably the greatest driver for species extinction. It can lead to a direct extinction by the individual populations being removed with the habitat, or it can lead to an indirect extinction by "facilitating the establishment of an invasive species or disease agent, improving access to human hunters, or altering biophysical conditions" (Causes and Consequences, 24). The Millennium Ecosystem Assessment compares the effect of habitat destruction to other species extinction drivers, specifically with regards to forest and dry land ecosystems, in the following chart:



While other species extinction drivers indefinitely contribute to the loss of biodiversity, it is obvious that habitat change has the greatest impact and shows no promise of ceasing in the future. Overexploitation often occurs in conjunction with habitat destruction. In order to more easily reach the exploited resources (ex: oil, minerals, timber, etc.) direct routes are often constructed from resource to human to increase accessibility. The construction of such routes obviously results in habitat destruction (Causes and Consequences, 22). Many biologists will agree that after habitat destruction, invasive species is the next leading cause of species extinction. Invasive species are defined as “plants, animals, and micro-organisms that have been relocated to environments outside of their natural past or present distribution. They are harmful species whose introduction or spread threatens the environment, the economy or society” (Smith, 276). Invasive species can easily cause the extinctions of species natural to a particular ecosystem by competing for scarce resources (food, nesting sites, etc.). In addition, invasive species can introduce pathogens that native species cannot fight off (Causes and Consequences, 22). Climate change or global warming, easily the most frequently addressed environmental problem, also plays a role in species extinction. According to the

Guide to Ecology, climate change can affect species in 5 main ways:

1) Alteration of species densities (including community composition and structure)
2) Range shifts (upward in elevation)
3) Behavioral changes such as the phenology (seasonal timing of life events) of migration, breeding, and flowering
4) Changes in morphology (ex: body size)
5) Reduction in genetic diversity that leads to inbreeding depressing

While the impact climate change has on biodiversity will definitely continue to increase until widespread societal improvements are made to reduce the speed and intensity of the Earth's warming, the impacts of other species extinction drivers can be lessened more easily. With regards to climate change, human activity is an indirect cause of species extinction. In other words, human activity has been linked to climate change, and climate change is the cause of species extinction. A similar relationship exists between human activity and invasive species. Trade and tourism are common reasons for the arrival of invasive species, which then disturbs natural ecosystems. Once the invasive species has arrived, it is difficult to thwart its destruction. To the contrary, habitat destruction is a direct cause of human activity, whether for the purpose of resource exploitation, commercial expansion, or relieving population pressures in surrounding areas. A change in human activity to reduce the leading cause of species extinction, habitat destruction, would undoubtedly prove to lessen the severity of biodiversity loss and encourage continued ecosystem functionality.

Changes in human activity that could achieve such positive results for biodiversity have been suggested through various arguments that stress its importance. These arguments are based on the indirect drivers that were previously discussed. The drivers of science and technology and culture/beliefs have made strong but essentially insufficient arguments outlining the importance of biodiversity. In further discussion and comparison of these arguments, the driving economic factor will prove to provide the greatest hope for maintaining biodiversity. The ecological importance of biodiversity and the extent to which it is declining is dealt with in the realm of science. Scientific findings are the backbone of all environmental policies and are necessary to deem if a policy is having a positive impact. While we rely on policymakers to address environmental problems (and economists to address how to do so in a cost-effective manner), we rely on environmental scientists to introduce them. The scientists most closely connected to the problem of biodiversity loss (beginning at the genetic diversity level) are known as conservation biologists. Conservation biologists can usually tell us what species are threatened, the rate of species extinctions, how/why species are being threatened (what human activities have offset ecosystem balances), and how the extinction of one species can cause a similar extinction in others (Causes and Consequences, 26). While data on such topics may be startling, it does not necessarily provoke human interest as the direct connections between species conservation and human well being may not be apparent. To address such connections, we rely on the interactions and cooperation of conservation biologists, environmental scientists, economists, policymakers, and other experts in the field. To the conservation biologist, maintaining biodiversity is not important in so much that it directly affects human well being but rather the importance of biodiversity is rooted in the idea of Earth's uniqueness of life and its connection to evolutionary processes (O'Riordan, 3). In his book "Biodiversity, Sustainability, and Human Communities," Tim O'Riordan states "In short, biodiversity loss means, at the very least, contributing to undermining the capability of life to survive and reproduce itself with vigor and reliability" (O' Riordan, 10). In other words, biodiversity on Earth supports the various unique life forms that comprise functioning ecosystems, and for that reason it must be protected. Against other reasons for protecting biodiversity (such as its monetary value) O'Riordan warns of "…the danger of trying to place a market-equivalent value on a mystery for which we should be more in awe than in arithmetic" (O'Riordan, 3). To O'Riordan and other environmental scientists, the value of biodiversity is in its amazing capability to sustain adaptable and successful life on Earth. The potentiality that life may not continue as it naturally should, supported by scientific findings on species extinction/habitat destruction rates, drives the scientist's insistence for strict protective policies.

While the focus on science in addressing the problem of biodiversity loss undoubtedly provides the concrete facts necessary for its remediation, it is essentially ineffective in triggering human action. The problem with presenting scientific data as a means to evoke change is that it does not appeal to individual interests and concerns. This is not to say that mankind is inherently selfish and can only care about that which directly affects him. Rather, scientific data usually address only the "what is" and not the "why this is significant" and "what can/should be done." Data is often in the form of statistics or far-projected extrapolations beyond the average person's scope of understanding. For example, some data from the Millennium Ecosystem Assessment states:

> Since 1750, the atmospheric concentration of carbon dioxide has increased by about 32% (from about 280 to 376 parts per million in 2003), primarily due to the combustion of fossil fuels and land use changes. Approximately 60% of that increase (60 parts per million) has taken place since 1959 (Millennium Ecosystem Assessment, 18).

Statements like the above, while dense in information, fail to address the big picture that humans can more easily relate to. Unless environmental science is your expertise, it would be difficult to understand the implications of such a finding and rather than dive into the personally uncharted realm of atmospheric carbon dioxide concentrations, most people remove themselves from the topic altogether. As a result, while we may accept such facts, we usually do not understand their significance. Therefore we are unlikely to act solely on the basis of scientific findings.

Another argument for the importance of biodiversity is the ethical argument, rooted in the culture/beliefs driver of ecosystem change. The ethical argument uses moral obligations to the preservation of nature as its force and it is rooted in several branches of philosophy. Throughout history, western thought has been based on the idea of anthropocentrism. According to this idea, human beings and their interests are the only focus of moral concerns. The natural world and its nonhuman inhabitants need not be given any kind of likewise moral consideration (Coppola, 137). This all changed in the 19th century, as environmentalists such as John Muir and Aldo Leopold introduced a new idea to society known as biocentrism. Biocentrism is the opposite of anthropocentrism. According to biocentrism, value is found in the continued existence all of living beings, not just humans. In other words, human beings and their interests are not more important than other forms of life on Earth (Coppola, 137). A central idea of this position that Leopold noted was that humans were not the center of ecological communities but rather were "plain members and citizens of it" (Coppola, 140). Given this idea, we should not act to benefit ourselves if our actions will be detrimental to other life forms in our community. Viewing the entire Earth as a community itself (just as we had viewed it as an entire ecosystem earlier), we can extrapolate these philosophical ideas to encourage the protection and respect of all life on Earth, or, in other words, the maintenance of biodiversity through species conservation. After examining the philosophy behind it, the ethical argument is easily applicable to the problem of biodiversity loss. Most simply, mankind has a moral obligation to preserve all species on Earth and to not take actions that harm species other than its own. This moral obligation comes from the idea that all species have intrinsic value. If mankind acts only to benefit himself without consideration of the natural world, he is selfishly valuing his interests as greater than the community of which he is a part. This argument is most famously exemplified by animal rights groups (ex: PETA – People for the Ethical Treatment of Animals) through attributing human standards of moral decency to animals. In addition, environmental groups frequently use this "moral obligation argument" to gain support for species/habitat conservation.

The problem with the ethical argument is that it is based on a uniform standard of morality. The truth of the matter is that such a standard does not exist as individuals each respond differently to their own moral compasses. As a result, the ethical argument is not an effective way to implement environmental policies. We can consider other laws to further exemplify this, such as seatbelt laws. Beginning with the philosophy behind the law, we can assume that human life is considered inherently valuable. Therefore, we have a duty to protect human life and avoid actions that can destroy it. We recognize that automobiles are dangerous and result in countless human fatalities every year. In order to protect human life from an automobile fatality, seatbelt laws are implemented and enforced. An important point to note is that the universal consensus that human life is valuable overrides any one individual's choice whether to wear a seatbelt, displaying the power of the philosophy behind the law. An environmental law based on the same thought process would not get nearly as far because the philosophy behind it is not accepted universally. It does not have as much power. Most people do not value other species as equal to humans, making it difficult to apply philosophical ideas of intrinsic life values in support of their preservations.

Another problem with the ethical argument is that it is too general. Biocentrism stresses the value of all living beings; so all existences would need protection. While biodiversity definitely requires species conservation, it must be in accordance with ecosystem balance. Too many of a species is just as great a problem as too little of a species. Biodiversity is not about protecting all life forms for their individual value, for that would be impossible and against natural processes. Rather, variation in life forms is what must be protected, which is why species conservation efforts are directed towards those whose populations are threatened. Nancy Coppola explains how the ethical argument stressing the value of all life forms may actually do a disservice to maintaining biodiversity in saying, "If all life is valuable and deserves to be protected, then there is no special reason to protect endangered or threatened species. The individual members of an endangered species, as individuals, are no more nor less important and valuable, than the individual members of a plentiful and thriving species" (Coppola, 168). Consider the event of an invasive species that disrupts a naturally functioning ecosystem. According to biocentrism, the lives of the individual invasive species are still intrinsically valuable, even if they are causing declining populations of other species in the ecosystem. How do we decide what to protect if all life has intrinsic value? To say that only endangered species must be protected on the basis of this argument would undermine its philosophical beliefs. Environmentalist Jason Scorse also addresses this issue with the implications of an ethical argument. According to Scorse, “Saying that all life has intrinsic value or is sacred is in some sense saying that all life is priceless. The problem with such a view is that it is impossible to compare the relative worth of one form of life with another if they are both priceless” (Scorse, 102). If all life is priceless, we cannot assert that saving one species is more important than another. While the ethical argument that all forms of life are valuable and must be protected may be most in tune with our sense of morality, and certainly provoke action of special interest groups dedicated to this belief, it is not practical nor will it yield effective environmental policies. Rather, a more neutral approach is required in order to creating lasting changes.

The final argument for maintaining biodiversity, and the argument that will be discussed in the greatest detail as the highlight of this report is the economic importance of biodiversity. In economic theory, intrinsic value belongs to humans only. The only value of nonhumans comes from the extent to which they provide resources/services that are valuable to humans. In other words, saving the polar bear is valuable only if its existence benefits human welfare (Goodstein, 26). This anthropocentric view is completely contrary to the ethical argument that was previously discussed as stressing the intrinsic value of all life forms, regardless of their relations to human life. This argument is also contrary to the ecological argument that values biodiversity for its support of unique life on Earth and importance to evolutionary processes. The economic argument in support of biodiversity draws upon the direct and indirect effects that maintaining biodiversity has on the economy as a whole. Directly, biodiversity plays an economic role in natural resource creation for production inputs, eco-tourism, pharmaceuticals, agriculture pollination, cooling cities, and resilience to natural disasters (Smith, 267). Indirectly, biodiversity affects the ecosystem services that humans utilize on a regular basis and that contribute to their well being. Because ecosystems provide so many varied services that have both market (measurable) and nonmarket values, it is difficult to give one explanation as to why they are economically valuable. To exemplify their economic importance, consider the universal good of food, as provided naturally from a functioning ecosystem. When a predatory species becomes extinct, the population of its food source (perhaps a vermin) goes unchecked and can increase exponentially. This population needs to eat as well, and in doing so it invades a nearby farm and destroys an entire harvest of wheat. All of the monetary profits that would have resulted from that harvest are now lost. We can also expect the price of wheat from successful harvests to increase, because their total supply is lower. Perhaps only half the harvest was destroyed, but the remaining half was unknowingly contaminated so that people who consumed it became sick. These sick people will need to be treated, which will be reflected in increased medical costs. It is easy to get caught up in the extrapolations from a hypothetical situation. However, this scenario is not far-fetched, and the food industry is experiencing countless similar disasters combined with increasing population pressures. In addition, this example only related the ecosystem service of providing food. The loss of biodiversity has detrimental economic effects on all ecosystem services, which will be more specifically discussed later in this report. While the economic argument may force us to face the most startling and dreary realities about our current consumption, it can provide the incentive for change. While the ecological and ethical arguments undoubtedly contribute to the cause of maintaining biodiversity, they lack the proper incentives present in the economic argument. Therefore, with support of other ecosystem change drivers, economics provides the greatest hope of slowing the rampant and persistent problem of biodiversity loss.

The next question to address is how to get people to reduce activity that threatens for species extinction and take action to preserve biodiversity through protection and conservation.

Making people aware of the problem of biodiversity loss from species extinction is only part of the battle. The problem requires action, and action requires motivation. Unfortunately, knowledge and moral senses of responsibility are not enough to motivate the average person to take up arms against species extinction. As previously discussed, more often than not we feel too detached from environmental problems to be sensitive to their eventual repercussions. Even with the direct connections established between ecosystem functionality and human well being, courses of action to address this problem are unclear, disorganized, and sometimes contradictory. With an economic approach I believe we can provoke action and establish systematic changes in how we view the problem of biodiversity loss to prevent a future of ensured ecological catastrophe.

IV) Economics and the Environment:

Why is the use of economics necessary to solve the problem of biodiversity loss? The answer is that we live in a capitalistic society that values money, a lot. Whether through maximizing profits or minimizing costs, the goal is the same: to increase wealth. From a formal definition, economics is "the study of the allocation of scarce productive resources among alternative uses for those resources with the objective of maximizing some given goal or set of goals" (Coppolla, 233). "Scarce resources" is a term most environmentalists are familiar with, as it perfectly describes our currently disappearing natural world. From natural resources to endangered species, the limitation on the quantity readily available (or the inability for natural replenishment to keep up with societal growth) is becoming more and more apparent. While the market system of economics definitely has flaws (which will be addressed), some adjustments to the structure could provide the deepest understanding of environmental problems and the greatest hope in reaching solutions. Through a discussion of underlying economic principles, resource valuation, and different types of economic analyses, the necessary relationship between the natural world and economics will become clear. In addition, the limits of economic modeling will call upon political institutions to provide assurance for continued economic and environmental health.

As the study of the allocation of scarce resources, economics provides an informative look into the decision-making behavior of individuals. Because individual choices and the circumstances surrounding those choices are unique, economic modeling relies on the acceptance of several assumptions. Without these assumptions, economic models would be essentially useless. Economist Gregory Mankiw addresses these assumptions in his "Principles of Economics." While Mankiw discusses 10 total principles, we will only be focusing on the first 4, which outline how people make decisions. These principles are as follows:

1. People face trade offs. In order to acquire something, you must give up something else, whether it is another good, time, or money. This is because resources are scarce and cannot be used for all purposes at all times. Environmental quality is often considered a trade off with business ventures. Trade offs occur within environmental policies as well. With specific regards to biodiversity, trade offs must be made between species preservation. In other words, the time/money devoted to preserving one species reduces/eliminates the time/money that can be devoted to preserving another species. There are trade offs to address in every decision-making process.
2. The cost of something is what you give up to get it (opportunity cost). Decision makers must take into account obvious costs as well as the implicit costs. For example, the

obvious costs of establishing protected areas would include the price of the land (if privately owned), continued maintenance of the land, and defense of the land from ill intentions. The implicit costs would be the profits forgone in the decision to not use the land for a factory or other business. Implicit costs can viewed as the second-best option to any decision. They are what you give up in order to pursue the chosen path.

3. Rational people think at the margin. A rational decision maker takes action if and only if the marginal benefit of the action exceeds the marginal cost. We assume that most decision makers are rational in that they act in a way that benefits their well being. If the costs of an action were greater than the benefits resulting from such an action, it would not make sense for the rational person to act. For example, if the measured costs of creating a protected area to maintain biodiversity were greater than the benefits associated with the creation of said protected area, it would not make sense economically to create the protected area.
4. People respond to incentives. Behavior changes when costs or benefits change. Without a reason for one to modify his actions, he will continue said actions until their benefits no longer exceed their costs. Incentives can be used to both encourage and discourage specific behaviors through "rewards and punishments." When gas prices increase, people have an incentive to drive less to reduce their costs. Similarly, if the cost of garbage disposal was determined per pound of waste produced, people would have an incentive to reduce their waste production. Incentives do not necessarily have to be of direct monetary value, though it does make them most likely to be effective.

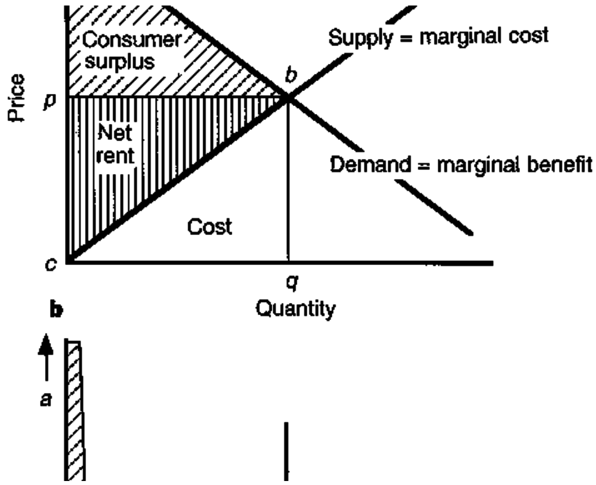
These four principles create the backbone behind economic theory and application. They are important in understanding the concepts behind the creation of economically efficient policies, specifically with regards to the environment. In addition, they address goals/desires in a practical manner that accepts compromise. Economists approach environmental problems with these principles in mind to strike a balance between desired economic growth and desired environmental quality. While this point of balance may not maximize economic growth or environmental quality individually, it reflects the legitimacy of some environmental degradation given the associated level of economic productivity.

Finding a balance between environmental quality with respect to biodiversity and economic growth relates directly to the first economic principle discussed, which is that people face trade offs. The questions to consider in this trade off are how much biodiversity loss are we willing to accept for continued economic growth? How much economic growth are we willing to sacrifice for greater biodiversity? This apparent trade off reflects the utility function of economics. The utility function asserts a positive relationship between the consumption of goods and utility (happiness) acquired from consumption, under the assumption that more is better (Goodstein, 27). Unfortunately, greater consumption also results in greater environmental stresses, such as pollution. Specifically with regards to biodiversity, habitat destruction resulting from pollution and the expansion of industry is the greatest driver of species extinction (Causes and Consequences, 25). As a result, the utility function is written as follows:

$$\text{Utility}_A = U_A(\overset{+}{X}_A, \overset{-}{P}_A)$$

The utility of specified individual ‘A’ is positively affected by consumption, X, as indicated by the plus sign above X, and negatively affected by pollution, P, as indicated by the minus sign above P (Goodstein, 28). Such a simple utility function exemplifies the historical tension between economists and environmentalists, each fighting for the upper hand to influence the total utility outcome of the individual. While this battle of economics vs. the environment may persist in the short run, it will not hold in the long run when the "more is better" assumption of consumption is thwarted by the law of diminishing marginal utility, and when the ecosystem damages from pollution affect the production costs of goods/services (costs that will be passed onto consumers). The conflict of interests as reflected in the utility function fails to recognize the importance of biodiversity to the success of industry and the relationship between ecosystem functionality and human well being. As a result, the utility function is not an accurate measure of the relationship between economics and the environment, or more specifically, biodiversity. In order to measure this relationship to effectively address the trade off (if one truly exists), we must first allocate comparable value to both economic productivity and environmental biodiversity.

The proper economic valuation of goods and services is critical in considerations of trade offs, opportunity costs, marginal benefits vs. costs, and the use of incentives. Unfortunately, when it comes to environmental goods such as biodiversity within ecosystems, this valuation is difficult to assess. With regards to market goods, meaning goods that are traded in a market, value is simply the equilibrium price in the market, as reflected in the following basic supply and demand graph (Costanza, 255):



The equilibrium price of the good, otherwise known as the value of the good, is the point at which the supply and demand curves intersect. This is also the point where marginal costs are equal to marginal benefits. In relation to principle 3 (rational people think at the margin), we can see how this price value makes sense because people will continue to act, or more specifically to this model consumers will continue to demand a particular good, as long as marginal benefits are greater than marginal costs. Similarly, suppliers will continue to produce goods for consumption as long as marginal benefits are greater than marginal costs. In relation to principle 4 (people respond to incentives), suppliers will have an incentive to continue producing goods as long as consumers are demanding them in an effort to maximize profits. Therefore, the equilibrium price of a market good as determined by the market interaction between consumers and suppliers is an efficient measure of the true value of the good.

However, market goods are not the only kinds of goods that are available to consumers. Ecosystems and the services they provide are widely considered nonmarket goods (although they may provide market goods as well). Nonmarket goods, such as clean air, fresh water, and species variation, are not traded between supplier and consumer on a market. As a result, their true values cannot be revealed by market interactions establishing an equilibrium price (Costanza, 255). Assigning a quantifiable value to an intangible good such as biodiversity is a difficult task. However, without a valuation (even if it is not necessarily exact) our decisions regarding environmental problems will lack any feasible support. Many people argue that trying to value intangible ecosystem services (such as aesthetics and long term benefits) is similar to trying to value life; both are nearly impossible and controversial in just the attempt. However, almost everyone will agree that ecosystems indefinitely have value, just as life has value. The problem is that this value is not quantified into relative terms but rather it is implied through societal actions (Costanza, 255). In order for this value to become comparable, many economists argue that it needs to be translated into monetary terms. As Jason Scorse discusses,

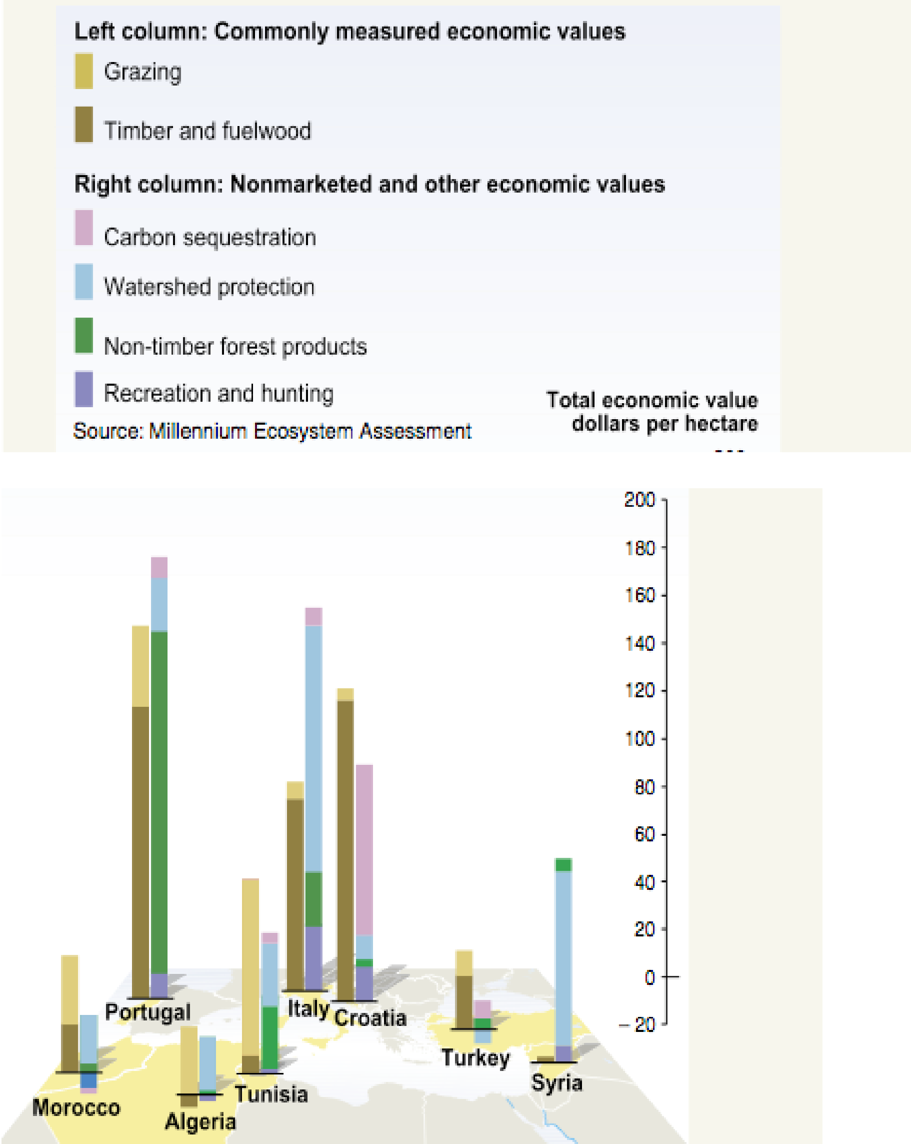
> "Money provides a convenient metric. To the extent that we can translate societal costs and benefits into monetary values, we can easily compare them. This can help us choose priorities and make the most cost-effective choices" (Scorse, 22).

In other words, the universal value of money makes it an effective means of comparison. When a good/service is accurately expressed in monetary terms, its value can no longer be questioned. Unfortunately, uncertainty will always exist regarding the accuracy of a monetary value relative to actual value, as will be discussed.

The countless services ecosystems provide as discussed by the Millennium Ecosystem Assessment presents the challenge of quantifiable valuation in monetary terms. Ecosystem services that are direct and measurable, while still difficult to quantify, are much easier to catalog. For example, a river that provides low-cost transportation can be estimated in value by comparing transportation costs between the river and the next best option. Ecosystems that provide natural resources (ex: timber, oil, food) that can be traded on markets also have obvious consumptive values that must be added in the calculation of the total ecosystem value. In addition, recreational values can be calculated through behavioral traces of the uses of ecosystem services. For example, many recreational activities directly related to the environment, such as camping, fishing, hiking, etc. require monetary purchases in the form of equipment or entrance fees which can be used to reflect the value of the services themselves. These measures of value, while imperfect, are relatively noncontroversial (Scorse, 29). Controversy erupts with regards to indirect ecosystem services values and passive use values. For example, coral reefs provide habitats for fish. While fish can be traded on commercial fisheries markets and their values calculated accordingly, fish also contribute to the species variation within coral reefs, and this biodiversity value is not accounted for (Costanza, 255). The difficulty and uncertainty in assessing the nonmarket values of ecosystem services forces many economists to account for market values only. This is obviously not an accurate reflection of the total value of an ecosystem as the nonmarket values of an ecosystem are often greater than the market values. This is exemplified in the Millennium Ecosystem Assessment with regards to forest ecosystems, which reveals the following:

Figure 3.2. Annual Flow of Benefits from Forests in Selected Countries (Adapted from C5 Box 5.2)

In most countries, the marketed values of ecosystems associated with timber and fuelwood production are less than one third of the total economic value, including nonmarketed values such as carbon sequestration, watershed protection, and recreation.



The obvious flaws in the valuation of nonmarket ecosystem services are frustrating to both economists and environmentalists alike. Economists struggle to grapple with the seemingly unquantifiable nature of ecosystem services, and environmentalists struggle to grapple with the apparent under-valuation of the natural world. Currently, the only unbiased and systematic approach to valuing ecosystem services is measuring willingness to pay. "Willingness to pay" refers to how much people are willing to pay for ecosystem services or in other words, how much they value ecosystem services in monetary terms (Scorse, 30). It can be measured through revealed preferences, which would include averting behavior, wage differentials, travel costs, differences in housing prices, etc. Revealed preferences are the values deducted from behavior. For example, people tend to move out of polluted areas so there must be a wage premium or reduction in housing prices to encourage people to stay (Field, 149). The other way to measure willingness to pay relies on a contingent valuation survey technique. In this survey technique, participants are interviewed and presented with hypothetical situations regarding ecosystem protection or preservation. Eventually the participants will be asked directly how much they would be willing to pay for a particular action that would improve ecosystem functionality, such as restoration efforts or efforts to prevent further damages (Scorse, 30). While these measures of willingness to pay can be helpful in determining pricing structures/fee to best encourage human/environment interactions through visitations to environmental parks and monuments, they are not an effective valuation of ecosystem services. This measurement fails to account for the fact that most people do not know of/understand the strong relationship between ecosystem functionality and human well being, as earlier discussed from the Millennium Ecosystem Assessment. This lack of information will make contingent valuation responses biased and not credible. The obvious difficulty in determining a quantifiable value for ecosystems and their services that can be compared to the value of market goods has led to a different approach to this problem. In a cost-benefit analysis we can compare the costs and benefits of ecosystem services to determine an idea of value. Although this analysis does not provide a quantifiable value measurement in monetary terms, we have discussed that such a goal is nearly impossible and uncertain at best. Rather, in a cost-benefit analysis, we can value the costs and benefits separately (as opposed to trying to value the entire ecosystem and/or its services together) and compare them not as a means of quantifying value but in order to create cost-effective environmental policies. A cost-benefit analysis is not a method of valuation in itself, but rather it is a tool to be utilized by policymakers as a reflection of estimated value (Goodstein, 191). As Jason Scorse discusses,

> Economists contend that it is preferable to make these valuations and the assumptions that accompany them transparent and an integral part of the decision-making process. This does not mean that any action where costs are greater than benefits is unwarranted; only that good reasons should then be provided for pursuing such a course (Scorse, 40).

In other words, cost-benefit analyses should not be used alone to suggest that when benefits are greater than costs, action is indefinitely warranted and vise versa, but they should provide insight as to where regulatory policies will be most valuable and effective.

V) Cost-Benefit Analysis of Biodiversity

To conduct a cost-benefit analysis of an entire ecosystem and its services would be quite vague and uncertain. In addition, such an analysis would be essentially useless in creating policies for specific environmental problems. As we are focusing on biodiversity in this report, we will conduct a cost-benefit analysis on said topic. In other words, what are the costs of maintaining species variation compared to the benefits of maintaining species variation? As these questions must first be answered separately, we will begin with the costs related to biodiversity. The costs of maintaining and protecting biodiversity can be broken down into several categories including social opportunity costs, environmental costs, and enforcement costs. Social opportunity costs (recall from economic principle 2: opportunity costs are what is given up to acquire something) reflect the trade off principle. If certain resources are used to protect biodiversity, they cannot be used elsewhere because resources are limited. In other words, making biodiversity "better off" will inevitably make some other industry worse off (Field, 160). Environmental costs include the direct costs of installing new physical capital (ex: the creation of a protected area for a particular species) and the unforeseen consequences of environmental regulation (ex: if the newly protected habitat of a species contains an abundance of timber that can no longer be accessed and so the price of timber increases) (Field, 161). Unforeseen consequences can be quite controversial. For example, the Endangered Species Act of 1973 "requires protection of a certain type of natural capital – species – regardless of the cost" (Goodstein, 266). If an endangered species be found on a property, either public or private, development would in theory be prohibited, regardless of the paid-for cost of that property. Land owners most likely would not know of the existence of an endangered species in their purchase, otherwise they probably would not make the purchase for development would not be allowed. These unforeseen compliance costs have been criticized as being too strict and high as well as unfairly distributed (Goodstein, 267). Enforcement costs would be costs associated with making sure a regulation is followed and sanctioning those who violate it (Field, 162). Considering the Endangered Species Act, the enforcement costs would include the monitoring of land to prevent any unlawful development and monitoring of the specified endangered species. Other than the unforeseen costs, environmental costs and enforcement costs can be estimated using an engineering approach. An engineering approach involves adding up "all the expected expenditures by firms on equipment and personnel, plus local state and federal government expenditures on regulatory efforts, including the drafting, monitoring, and enforcing of regulations" (Goodstein, 168).

The greatest difficulty in estimating costs is with regards to the social opportunity costs. In other words, what are the benefits lost in biodiversity protection? The issue of biodiversity is especially tricky because it is not either being maintained or not, but rather it depends on continuous species protection and functional success, as explained through the interdependent characteristic of ecosystems. Just as all economic analyses make assumptions, we will assume for simplicity's sake a "black and white" stance on the issue. To determine the opportunity costs, we must measure the benefits of the next best option. In accordance with the "black and white" simplicity stance, the next best option (and only option) to protecting biodiversity would be not protecting biodiversity. The benefits of no biodiversity protection through ecosystem maintenance and species conservation would appear to be unlimited access to natural resources and economic development. However, in our knowledge of the connection between ecosystem functionality and human well being and the interdependence between the natural world and society, we know that such "benefits" do not actually exist. Unlimited access to natural resources and unrestrained development have associated risks that make these "benefits" more like "costs." The risks associated with biodiversity decline can be broken down into the categories of operational risks, regulatory and legal risks, reputational risks, market and product risks, and financing risks (Smith, 265). Operational risks include higher risks due to resource scarcity resulting from unrestricted exploitation, and the greater potential for direct loss of assets resulting from the lowered resilience of degraded ecosystems. Regulatory and legal risks include lawsuits filed by local communities affected by the biodiversity loss and decline of ecosystem functionality. These affects are inevitable, as we know the relationship between ecosystem functionality and human well being as presented by the Millennium Ecosystem Assessment. Reputational risks would include pressures to firms to adopt environmentally conscious "green" practices on the principle that degraded ecosystems are bad (even though access and development is unrestricted in this hypothetical scenario). Similarly, market and product risks include the loss of customers who prefer green products/production practices (Smith, 266). Finally, financing risks include the investment challenges that may result from operations considered high risk to be effected by inevitable ecosystem change (Smith 266). In other words, the effects that a declining quality ecosystem may have on an industry will decrease consumer confidence in that industry, and this uncertainty will hinder investments. These undeniable risks associated with the "benefits" of not protecting biodiversity may as well delete the "social opportunity costs" factor of the total costs equation of biodiversity altogether. In fact, it can be argued that these risks add to the benefits side of the analysis. As a result, the costs of maintaining biodiversity would simply include the environmental costs (direct costs of physical capital and unforeseen consequences of regulations) and enforcement costs.

Although we have determined what the costs are, they will not have relative meaning until they are compared to the benefits to complete the analysis. The benefits of maintaining biodiversity are abundant, as discussed in the relationship between ecosystem functionality and human well being. While these relationships may not all be measurable in their benefits, several specific benefits are. The economic benefits from protecting biodiversity include, though are not limited to, eco-tourism, pharmaceuticals, watershed management, pollination in agriculture, cooling cities, and resilience to natural disasters (Smith 266). Eco-tourism regards the diverse ecosystems that contribute to the tourism industry, such as the Great Barrier Reef. In many less developed countries, eco-tourism is a substantial contributor to GDP (Gross Domestic Product), which is a measurement of all final goods and services produced in a country. The eco-tourism market has reportedly been growing 20-34% per year, which is three times faster than the whole tourism industry. In addition, by 2015, the total worth of global eco-tourism is estimated to be approximately $473 billion (Smith, 267). Regarding pharmaceuticals, approximately 25-50% of drugs from the $640 billion per year industry are derived partly from natural sources. These natural sources rely on functioning ecosystems to continue in their existences (Smith, 267). Without them, countless amounts of money would be lost to research and develop appropriate substitutes (if any exist). Similarly, the herbal and alternative health product markets which relying significantly on ecosystem biodiversity (as the products are more composed of natural sources) are worth an estimated $22 billion (Smith, 267). Watershed management refers to the role of marshes/wetlands in wastewater filtration. This natural contribution of ecosystems to a necessary service is often overlooked. For example, New York City recently saved hundreds of millions of dollars by preserving the environmental quality of its natural watershed as opposed to building a water purification plant (Smith, 267). In discussion of the benefits from pollination in agriculture, over 75% of global crops depend on pollination. A study in 2005 concluded the economic value of pollination to be $201 billion, which is 9.5% of the total economic value of world food production (Smith, 267). Worldwide, cities are planting trees to help offset the rising surface temperatures of global warming. Global warming is a dramatic and increasingly problematic issue that threatens the well being of society worldwide. Any efforts to offset its effects cannot be marginalized. Studies have shown that mature trees can reduce air temperature by 2-5 degrees Celcius and reduce wind speed in cities that suffer cold winters. Economically, this translates to less money spent on cooling as a result of higher surface temperatures and less money spent on heating from winter wind chills (Smith, 267). Finally, one of the greatest benefits of maintaining biodiversity is its support of resilient ecosystems to natural disasters. Given the circumstances, natural disasters are essentially unavoidable. Therefore, a strong ability to recover from them will undoubtedly lessen their devastating effects on human life, the economy, and the environment. Michael Smith gives two excellent examples of why this recovery ability is of immeasurable importance. Smith notes,

> For instance, in Asia, the 2004 tsunami would have been less disastrous if the mangroves, serving as a natural barrier, had not been removed for tourism and shrimp faming; and in the northern Pakistan earthquake of 2005, local people claim that intact forest cover prevented landslides which cause extensive damage elsewhere.

The benefits of ecosystem resilience to natural disasters, along with the other discussed benefits of biodiversity, are greatly important to both the economy and human well being.

With the costs and benefits explained, the final part of the economic cost-benefit analysis is to compare them. It is obvious that the benefits of maintaining biodiversity are greater than the costs, which suggest the need for in its preservation. This conclusion is in accordance with the Environmental Protection Agency's ranking of environmental hazards in terms of their potential risks to the U.S. population. This ranking, as shown below, lists "Habitat alternation and destruction" and "Species extinction and loss of biodiversity" first and second as relatively high-risk threats to society, further supporting the conducted cost-benefit analysis conclusions of importance of maintaining biodiversity for ecosystem functionality and the human population.

TABLE 8.2 Relative Risks as Viewed by the EPA

Relatively High Risk
- Habitat alteration and destruction
- Species extinction and loss of biodiversity
- Stratospheric ozone depletion
- Global climate change

Relatively Medium Risk
- Herbicides/pesticides
- Toxics, nutrients, biochemical oxygen demand, and turbidity in surface waters
- Acid deposition
- Airborne toxics

Relatively Low Risk
- Oil spills
- Groundwater pollution
- Radionuclides
- Acid runoff to surface waters
- Thermal pollution

Source: U.S. Environmental Protection Agency (1990).

However, although the findings of the cost-benefit analysis support the cause of maintaining biodiversity, it is important to remember the earlier assertion of Jason Scorse that such analysis alone is not sufficient enough to insist on action. In other words, action should not be taken as a direct result of cost-benefit analysis findings but rather such findings should express where the allocation of limited resources (money, protection efforts, etc) would be most valuable.

Conclusion

At the conclusion of this report, I am hoping the above discussion will motivate action to preserve biodiversity. The current goal of economists and environmentalists alike is a sustainable future, which cannot be ensured unless biodiversity is protected. Sustainability is defined as "providing the typical person in a given society alive in the future with a standard of living, including both material and environmental welfare, at least as high as that of the typical person alive today" (Goodstein, 89). With the rapidly declining quality of ecosystems through a loss of biodiversity, the goal of a sustainable future will grow in difficultly until it is impossible. The economic value of biodiversity within ecosystems as reflected by the cost-benefit analysis, as well as the less powerful but still contributory ecological and ethical arguments, expresses its importance and is a great framework to use in encouraging its preservation. With this exemplified value and the four basic economic principles (people face trade offs, the cost of something is what you give up to get it, rational people think at the margin, and people respond to incentives), officials can effectively implement policies that are both economically and environmentally beneficial to continue the growth of productivity and maintain biodiversity. The ability of economics to create strong incentives to motivate behavioral changes in society is one that cannot be overlooked. This powerful driver of change, along with the other drivers discussed in this report such as scientific findings and moral senses will undoubtedly be an unstoppable force if implemented correctly. Therefore, what is finally left to do is implement the findings of this report into constructive economic and public policies that work towards the goal of maintaining biodiversity rather than against it.

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