ELSEVIER

Ecological Economics 39 (2001) 203–222

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

SURVEY

Economic valuation of biodiversity: sense or nonsense?

Paulo A.L.D. Nunes *, Jeroen C.J.M. van den Bergh

Department of Spatial Economics, Free University, De Boelelaan 1105, 1081 HV Amsterdam, Netherlands

Received 6 March 2000; received in revised form 19 July 2000; accepted 26 July 2001

Abstract

This paper critically evaluates the notion and application of economic, monetary valuation of biological diversity, or biodiversity. For this purpose four levels of diversity are considered: genes, species, ecosystems and functions. Different perspectives on biodiversity value can be characterized through a number of factors: instrumental vs. intrinsic values, local vs. global diversity, life diversity vs. biological resources, etc. A classification of biodiversity values is offered, based on a system of logical relationships among biodiversity, ecosystems, species and human welfare. Suggestions are made about which economic valuation methods can address which type of biodiversity value. The resulting framework is the starting point for a survey and evaluation of empirical studies at each of the four levels of diversity. The contingent valuation method is by far the most used method. An important reason is that the other valuation methods are unable to identify and measure passive or nonuse values of biodiversity. At first sight, the resulting monetary value estimates seem to give unequivocal support to the belief that biodiversity has a significant, positive social value. Nevertheless, most studies lack a uniform, clear perspective on biodiversity as a distinct concept from biological resources. In fact, the empirical literature fails to apply economic valuation to the entire range of biodiversity benefits. Therefore, available economic valuation estimates should generally be regarded as providing a very incomplete perspective on, and at best lower bounds, to the unknown value of biodiversity changes.

Keywords: Life diversity; Biological resource; Biodiversity; Monetary valuation

1. Introduction

Biodiversity requires our attention for two reasons. First, it provides a wide range of indirect benefits to humans. Second, human activities have contributed, and still contribute, to unprecedented rates of biodiversity loss, which threaten the stability and continuity of ecosystems as well as their provision of goods and services to humans (Pimm et al., 1995; Simon and Wildavsky, 1995). Consequently, in recent years many studies of biodiversity and its loss have appeared. This article critically evaluates the notion of biodiversity value and the application of economic, monetary valua-

* Corresponding author. Fax: + 31-20-444-60-04.

E-mail addresses: pnunes@econ.vu.nl (P.A.L.D. Nunes), jbergh@econ.vu.nl (J.C.J.M. van den Bergh).

0921-8009/01/$ - see front matter
PII: S0921-8009(01)00233-6

tion methods for its assessment. Monetary values of changes in biodiversity allow for a direct comparison with monetary values of alternative options, such as benefits of an investment project, thus facilitating cost-benefit analysis of biodiversity policies. In addition, they allow economists to perform environmental accounting to assess damages, and to carry out proper pricing. This study examines how the information provided by available studies on biodiversity valuation should be interpreted.

The organization of the article is as follows. Section 2 identifies different levels of diversity. Section 3 discusses alternative perspectives on biodiversity value. Section 4 offers a classification of biodiversity value, characterizes the approach adopted in the evaluation offered here, and discusses how to assess biodiversity value categories using particular valuation methods. Section 5 presents a survey of valuation studies at four levels of diversity. Section 6 discusses the range of empirical findings and evaluates these within the earlier presented framework. Section 7 concludes.

2. Multilevel diversity and types of biodiversity

An important step in discussing the notion of biodiversity value is defining biodiversity. The United Nations Convention on Biological Diversity (UNEP, 1992) defines it as '... the variability among living organisms from all sources, including terrestrial, marine and the ecological complexes of which they are part...' (art. 2, page 5). Biodiversity encompasses four levels, as shown in Table 1. This classification will turn out to be useful when discussing the economic valuation results later in Section 5.

At the most basic level is genetic diversity, which corresponds to the degree of variability within species. Roughly speaking, it concerns the information represented by genes in the DNA of individual plants and animals (Wilson, 1994).

Species diversity refers to the variety of species. Empirical estimates of this are characterized by a large degree of uncertainty. In fact, only about 1.5 million species have been described so far (Parker, 1982; Arnett, 1985), while scientists estimate that the earth currently hosts 5–30 million species (Wilson, 1988). Less than half a million have been analyzed for potential economic uses (Miller et al., 1985). Since genetic and species diversity are directly linked, the distinction between them is sometimes blurred. In this sense, phenotypic diversity vs. genotypic diversity is relevant.

Ecosystem diversity refers to diversity at a supra-species level, namely, at the community level. This covers the variety of communities of organisms within particular habitats as well as the physical conditions under which they live. A longstanding theoretical paradigm suggests that species diversity is important because it enhances the productivity and stability of ecosystems (Odum, 1950). However, recent studies acknowledge that no pattern or determinate relationship needs to exist between species diversity and the stability of ecosystems (Johnson et al., 1996). Folke et al. (1996) instead suggest that a system's robustness may be linked to the prevalence of a limited number of organisms and groups of organisms, sometimes referred to as 'keystone species'. It is also possible that the specific relationships depend very much on whether the abiotic environment is stable or not (Holling et al., 1995).

Functional diversity refers to the capacity of life-support ecosystems to absorb some level of stress, or shock, without flipping the current ecosystem to another regime of behavior, i.e. to

Table 1
Levels of biodiversity

Type of diversity	Physical expression	Valuation studies
Gene	Genes, nucleotides, chromosomes, individuals	Section 5.2
Species	Kingdom, phyla, families, genera, subspecies, species, populations	Section 5.3
Ecosystem	Bioregions, landscapes, habitats	Section 5.4
Functional	Ecosystem functional robustness, ecosystem resilience, services, goods	Section 5.5

Source: Turner et al. (1999).

another stability domain (Turner et al., 1999). This has been originally referred to as 'resilience' (Holling, 1973). Unfortunately, a system's functional robustness is still poorly understood and we often do not know the critical functional threshold associated with the variety of environmental conditions at different temporal and spatial scales (Perrings and Pearce, 1994). From a management point of view, a safe strategy seems to be requiring a minimum level of biodiversity for any ecosystem to be sustained. A low level of ecosystem resilience can cause a sudden decrease in biological productivity, which in turn can lead to an irreversible loss of functions for both current and future generations (Arrow et al., 1995). Functional diversity expresses the range of functions generated by ecosystems, including ecosystem life support functions, such as the regulation of nature's major cycles (e.g. water and carbon) and primary ecosystem processes, such as photosynthesis and biogeochemical cycling (Turner et al., 2000).

3. Alternative perspectives on biodiversity value

Given the four levels of diversity, it should be evident that there is no single notion of biodiversity. This section presents additional considerations which suggest that biodiversity value can be interpreted in various ways.

3.1. Instrumental vs. intrinsic values

Many people do not feel comfortable with placing an instrumental value on biodiversity. The common argument is that biodiversity has a value on its own—also known as 'intrinsic value'. A more extreme version of this perspective even claims that instrumental valuation of biodiversity, often translated in monetary terms, is a nonsense exercise (Ehrenfeld, 1988). Many others, however, accept placing a monetary value on biodiversity, arguing that this merely makes explicit the fact that biodiversity is used for instrumental purposes, in terms of production and consumption opportunities (Fromm, 2000). Two additional related motivations are that making public or private decisions which affect biodiversity implicitly means attaching a value to it, and that monetary valuation can be considered as a democratic approach to decide about public issues, including biodiversity ones.

3.2. Monetary vs. biological indicators

Monetary valuation of biodiversity is anchored in a economic perspective, based on biological indicators of the impacts of biodiversity on human welfare (Randall, 1988). Economic valuation of biodiversity leads to monetary indicators, regarded as a common unit for comparison and ranking of alternative biodiversity management policies. On the contrary, biological assessments of biodiversity value give rise to non-monetary indicators. These include, for example, species and ecosystems richness indices (Whittaker, 1960, 1972), which have served as important valuation tools in the definition of 'Red Data Books' and 'Sites of Special Interest'. It is not guaranteed, however, that monetary and biological indicators point in the same direction. They should best be regarded as complementary methods for assessment of biodiversity changes. Moreover, economic indicators should, where possible indirectly, be based on accurate biological indicators.

3.3. Direct vs. indirect values

The notion of direct value of biodiversity is sometimes used to refer to human uses of biodiversity in terms of production and consumption. The notion of indirect value of biodiversity has been associated with a minimum level of ecosystem infrastructure, without which there would not be the goods and services provided by it (Farnworth et al., 1981). Barbier (1994) recently described the 'indirect value' of biodiversity as '... support and protection provided to economic activity by regulatory environmental services...' (p. 156). In the literature, one can find other terms such as 'contributory value', 'primary value', and 'infrastructure value' of biodiversity, which all seem to point at the same notion (Norton, 1986; Gren et al., 1994; Costanza et al., 1998). Some of these authors subscribe to the opinion that monetarization of biodiversity benefits is possible, but that it will always lead to an under-estimation of the 'real' value, since 'primary value' of biodiversity cannot be translated in monetary terms. As Gowdy (1997) has recently said '... although values of environmental services may be used to justify biodiversity protection measures, it must be stressed that value constitutes a small portion of the total biodiversity value...'.

3.4. Biodiversity vs. biological resources

Whereas biodiversity refers to the variety of life, at various levels, *biological resources* refer to the manifestation of that variety. According to Pearce (1999), '... much of the literature on the economic valuation of 'biodiversity' is actually about the value of biological resources and it is linked only tenuously to the value of diversity...'. The precise distinction is not always clear, and the two categories seem to be somewhat overlapping. Therefore, care is needed when evaluating studies that claim to present economic values of biodiversity.

3.5. Value of levels vs. changes of biodiversity

Economists stress that the valuation should focus on changes rather than levels of biodiversity. Non-economists have frequently tried to value biodiversity levels, for instance, the recent example of value assessment of ecosystem services and natural capital for the entire biosphere level (Costanza et al., 1998). However, economic-theoretical support for such a valuation approach is weak. The reasons are that willingness to pay (WTP), or willingness to accept, are based on compensation or equivalence variations of a change, and that change should be relatively small in comparison with income levels.

3.6. Local vs. global diversity

The design of a valuation context involves important decisions about the spatial frame of analysis (Norton and Ulanowicz, 1992). Whereas biodiversity loss is usually discussed in a global or worldwide context, valuation biodiversity studies frequently address policy changes or scenarios defined at local, regional or national levels. Although this seems contradicting, it can be argued that biodiversity and its loss are relevant at multiple spatial levels, from local to global (Hammond et al., 1995).

3.7. Genetic vs. other life organization levels

Scientists face an important decision when valuing biodiversity: which level of diversity is being considered. Some scientists, especially from the natural sciences domain, tend to focus on genetic and species levels, whereas others, including social scientists, tend to study biodiversity at the level of species and ecosystems. Some unresolved issues are whether studying biodiversity at multiple levels leads to double counting, and whether sufficient information is available at each biodiversity level to perform valuation studies.

3.8. Holistic vs. reductionist approaches

According to a holistic perspective, biodiversity is an abstract notion, linked to the integrity, stability and resilience of complex systems, and thus difficult to disentangle and measure (Faber et al., 1996). In addition, the insufficient knowledge and understanding of the human and economic significance of almost every form of life diversity further complicates the translation of physical–biological indicators of biodiversity into monetary values. For these reasons, economic valuation of biodiversity is by many scientists regarded as a hopeless task (Ehrenfeld, 1988). On the contrary, a reductionist perspective is based on the idea that one is able to disentangle, or disaggregate the total value of biodiversity into different economic value categories, notably, into direct use and passive use or nonuse values (Pearce and Moran, 1994).

3.9. Expert vs. general public assessments

The general public valuation approach relies on the premise that individuals, from all educational levels and life experiences, are expected to participate in the valuation of biodiversity changes. Another view assumes that laypersons cannot judge the relevance and complexity of biodiversity-ecosystems-functions relationships. Instead, judgments and valuation of biodiversity changes should be left to experts, notably biologists. An example of an intermediate 'solution' is to let experts inform laypersons sufficiently before confronting them with the valuation exercise (NOAA, 1993).

3.10. Conclusion

It is clear that many different biodiversity value perspectives can be distinguished based on the above nine considerations. This does not mean that one is right and the other is wrong. Evidently, it is crucial to know the perspective being adopted. The next section will clarify the relevant context for the subsequent evaluation of empirical valuation studies, while Section 6 will discuss these against the nine considerations discussed above.

4. Biodiversity as a source of economic value

4.1. General aspects of economic valuation of biodiversity

The general context of economic valuation of biodiversity can be clarified by looking at some of the perspectives implied by the discussion in the previous sections.

Economic valuation of biodiversity is based on an instrumental perspective on the value of biodiversity (Section 3.1). This means that the value of biodiversity is regarded as the result of an interaction between human subjects, and the object of valuation, namely biodiversity, changes therein.

Economic valuation provides a monetary indicator of biodiversity values (Section 3.2). The reason is that the theoretical basis of economic valuation is monetary (income) variation as a compensation or equivalent for a direct and indirect impact(s) on the welfare of humans due to a certain biodiversity change.

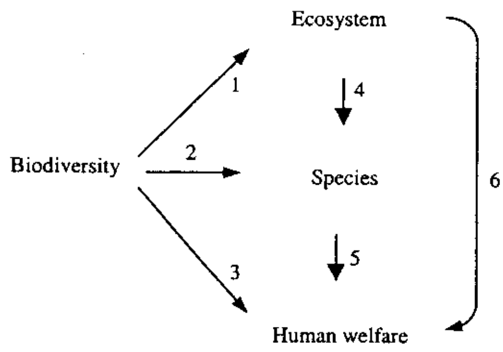

Fig. 1. Economic values of biodiversity.

Both direct and indirect values, relating to production, consumption and nonuse values of biodiversity are considered when pursuing economic valuation of biodiversity (Section 3.3).

Explicit biodiversity changes, preferably in terms of accurate scientific physical–biological indicators, are described in reference to specific levels of life diversity (Sections 3.4 and 3.7).

Economic valuation of biodiversity is operationalized through explicit biodiversity changes, preferably marginal or small, and thus involving the design of alternative biodiversity policy management options, or scenarios (Section 3.7).

Economic valuation of biodiversity changes is based on a reductionist approach value (Section 3.8). This means that the total economic value is regarded as a result of aggregating various use and nonuse values, reflecting different human motivations to biodiversity, as well as aggregating local values to attain a global value, i.e. a bottom-up approach (Section 3.5).

Economic valuation of biodiversity starts from the premise that social values should be based on individual values, independently of being, or not, an expert in biodiversity related issues (Section 3.9). This can be considered as consistent with democratic support of policies.

A more detailed discussion and evaluation has to wait until Section 6, after the economic valuation applications have been reviewed in Section 5.

4.2. A classification of biodiversity economic values

It is possible to identify and characterize the different value categories of biodiversity. Fig. 1 shows a classification of biodiversity values that is the basis of the evaluation of studies in Section 5. A first category, denoted by link $1 \rightarrow 6$, depicts biodiversity benefits in terms of ecosystem life support functions and preservation of the ecological structure in natural systems. The diversity of functions generated by ecosystems provides, in turn, the existence of demand for goods and services. Therefore, this value category can represent, for example, the benefits of flood control, groundwater recharge, nutrient removal, toxic retention, and biodiversity maintenance (Turner et al., 2000). A second biodiversity category value, denoted by link $1 \rightarrow 4 \rightarrow 5$, captures the value of biodiversity in terms of supply of ecosystem space or natural habitat protection. This can represent, for example, the impact of natural habitat destruction on the loss of wilderness areas and on the loss of natural areas related to high tourism and outdoor recreational demand.

A third category, denoted by link $2 \rightarrow 5$, captures the benefits in terms of an overall provision of species diversity. This value category can represent, for example, the indirect value of biodiversity on biological resources in terms of inputs to the production of market goods (e.g. the impact on revenues of pharmaceutical and agriculture industries that use plant and animal material to develop new medicines and new products (Myers, 1988; Simpson et al., 1996)).

Finally, a fourth category, captured by link 3, denotes a passive/nonuse component of biodiversity value, reflecting human moral considerations (e.g., the knowledge that biodiversity exists in nature independently of any use by humans) or reflecting human philanthropic or bequest considerations (e.g., the knowledge that biodiversity continues to exist in nature during the next generations).

4.3. Alternative biodiversity economic valuation methods and their degree of applicability

Some monetary indicators of biodiversity values are based on market price valuation mechanisms. These include the value of contracts, as recently signed by the pharmaceutical industry and governmental agencies, and the value of the financial revenues related to the tourism activities focused on the visits to natural areas of high outdoor recreational demand. In the absence of market prices for biodiversity values, which is commonly the case, certain techniques are needed to retrieve consumers' preferences. On the basis of the process through which valuation methods retrieve individuals' preferences one can distinguish two groups of valuation methods: revealed preference and stated preference methods. The group of revealed preference valuation methods explore the use of existing market data, based on notions of travel cost (TC), hedonic price (HP), averting behavior (AB), and production function (PF) (Mäler, 1988; Braden and Kolstad, 1991). These methods can be used to assess the above-mentioned value categories of biodiversity. The group of stated preference valuation methods are based on collecting data by means of questionnaires, including the contingent valuation (CV) methodology. One should not, however, consider these tools as universally applicable to all diversity levels or to all types of biodiversity values. Table 2 shows that certain valuation methods are more appropriate than others to address certain types of biodiversity value. For example, revealed preference methods can only be used for a limited number of biodiversity value categories, as they do not allow a monetary assessment of nonuse values. On the contrary, the CV method is in principle applicable for all biodiversity value categories. However, one needs to recognize that this method will fail for those biodiversity value categories that the general public is not informed about nor has experience with. Moreover, a questionnaire designed comprehensively enough to address changes in ecosystem life support functions and processes, such as changes of photosynthesis, water, carbon and other biogeochemical cycles, will almost certainly be too cumbersome to be utilized in a practical and effective way.

5. Empirical estimates

5.1. Introduction

The aim of this section is to provide a critical review, rather than a comprehensive survey, of representative biodiversity valuation studies. The discussion is organized as indicted in Table 2. First, valuation studies that focus on the assessment of biodiversity value in terms of genetic and species diversity are reviewed. Subsequently, the discussion is centered on valuation studies that pursue the assessment of biodiversity benefits in terms of natural habitat or ecosystem diversity. Next, we present some valuation study results on biodiversity values linked to the diversity of functions generated by ecosystems, including ecosystem life support functions, flood control and groundwater recharge. Finally, the nonuse or passive value component of biodiversity will be examined. The presentation will be kept concise, as the findings will be evaluated in the context of the adopted framework in Section 6.

Table 2
Total economic value of biodiversity

Biodiversity value category (Fig. 1)	Economic value interpretation	Biodiversity benefits	Methods for economic valuation (and their applicability)
2→5	Genetic and species diversity (Sections 5.2 and 5.3)	Inputs to production processes (e.g. pharmaceutical and agriculture industries)	CV: +
			TC: –
			HP: +
			AB: +
			PF: +
			Contracts: +
1→4→5	Natural areas and landscape diversity (Section 5.4)	Provision of natural habitat (e.g. protection of wilderness areas and recreational areas)	CV: +
			TC: +
			HP: –
			AB:+
			PF: +
			Tourism revenues: +
1→6	Ecosystem functions and ecological services flows (Section 5.5)	Ecological values (e.g. flood control, nutrient removal, toxic retention and biodiversity maintenance)	CV: –
			TC: –
			HP: +
			AB: +
			PF: +
3	Nonuse of biodiversity (Sections 5.3 and 5.4)	Existence or moral value (e.g. guarantee that a particular species is kept free from extinction)	CV: +
			TC: –
			HP: –
			AB: –
			PF: –

Note: the sign + (–) means that the method is more (less) appropriate to be selected for the design of the valuation context of the biodiversity value category under consideration.

Table 3
Bioprospecting agreements

Contractors	Study	Value
INBio and Merck (1991)	2000 samples of Costa Rica genetic pool	\$1 million
Yellowstone National Park and Diversa (1998)	Thermostable enzyme *Taq* polymerase and bacterium *Thermus Aquaticus*	\$175 000
Brazilian Extracta and Glaxo Wellcome (1999)	30 000 samples of Brazil biota	\$3.2 million

5.2. Genetic diversity and bioprospecting

Recent years have shown a sharp increase of interest in bioprospecting, i.e. the search among the genetic codes contained in living organisms for the development of chemical compounds of commercial value in agricultural, industrial, or pharmaceutical applications (Simpson et al., 1996). This is dominated by pharmaceutical research since most prescribed drugs are derived, or patented after natural sources (Grifo et al., 1996). This section considers assessments of WTP by the pharmaceutical industries for genetic diversity as input into commercial products. The marginal value of such input, often translated in terms of genetic information for medicinal purposes, is measured by its contribution to the improvement of health care. For example, research by the US National Cancer Institute on screening of plants over the last two decades yielded various, highly effective anti-cancer drugs (e.g. *paclitazel* and *camptothecin*) and anti-leukemia drugs (e.g. *homoharringtonone*) (Cragg et al., 1998).

Recent registrations and applications of bioprospecting contracts and agreements between states and pharmaceutical industries represent important benchmarks of monetary indicators for these types of biodiversity values. Estimates are shown in Table 3. The most noted of these agreements is the pioneering venture between Merck and Co., the world's largest pharmaceutical firm, and 'Instituto National de Biodiversidad' (INBio) in Costa Rica. At the moment of the signing of the contract, in 1991, Merck paid Costa Rica about \$1 million and agreed to pay royalties whenever a new commercial product was explored. Since then, INBio has signed contracts on the supply of genetic resources with Bristol-Myers Squibb, other companies and non-profit organizations (ten Kate and Laird, 1999; INBio, 2001). Another illustration of the market value of genetic diversity refers to the commercial agreement signed in 1997 between Diversa, a San Diego-based biotechnology company, and the US National Park Service. Diversa paid \$175000 for the right to conduct research on heat-resistant microorganisms found in hot springs in Yellowstone National Park (Sonner, 1998; Macilwain, 1998). More recently, a Brazilian company, Extracta, signed a \$3.2 million agreement with Glaxo Wellcome, the world's second largest pharmaceutical company, to screen 30000 samples of compounds of plant, fungus and bacterial origin from several regions in the country (Bonalume and Dickson, 1999). Despite the fact that these agreements show a positive economic value of genetic diversity, concern remains with respect to the fairness of such deals. Indeed, some environmental groups have been very critical, claiming that these are unequivocally 'biopiracy' actions (RAFI, 2001). Furthermore, genetic diversity may also give rise to a number of existence and moral values. These, however, are not the basis for the pharmaceutical industry's WTP, and therefore not captured through the market prices as reflected by the agreements.

5.3. Biodiversity and species preservation

Most of the valuation studies of species preservation have focused on single animal species. Table 4 lists some recent studies, all applications in the US, except for a Swedish CV study of wolf (Boman and Bostedt, 1995). The estimates are derived from CV applications and obtained from individual WTP to avoid a loss of a particular species. Most welfare gains accrue to the individuals and are based on recreation activities such as watching threatened or endangered species in their natural habitat, or simply reflect the well-being derived from the knowledge that such a species exists. The later case can be interpreted as relating to nonuse or passive use values. For example, van Kooten (1993) assessed the economic value of waterfowls in a wetland region in Canada; Loomis and Larson (1994) valued 'emblematic' endangered species, namely, the gray whale; and Stevens et al. (1997) valued the restoration of the Atlantic salmon in one river in the state of Massachusetts (see van Kooten and Bulte (2000) for more examples).

The interpretation of single species valuation studies should be taken with care, especially when the results are proposed as guidelines for policy design, since such estimates tend not to account for species substitution or complementary effects (Hoehn and Loomis, 1993). This is because the estimated values for single species can be affected by the availability of related species. Therefore, aggregate values for a group of species can differ depending on whether the total is calculated directly or indirectly, i.e. by summing the individual single species values. Alternatively, some economists pursue valuation of biodiversity at species level bearing in mind multiple species studies, see valuation results in Table 5. The estimates are higher than the single species value estimates, though not so high as one would expect, bearing in mind the initial single species estimates. For example, the WTP of the wolf study in Sweden alone corresponds to more than 70% of the WTP for 300 Swedish endangered species. The interpretation of such estimation results may be, however, heavily criticized in terms of CV design and execution (Carson, 1997). Nevertheless, some authors prefer to work with other categories of biodiversity value, namely, the value categories related to natural habitat, ecosystem functions and ecological services protection. These are discussed in the following sections.

5.4. Biodiversity and natural habitat preservation

A problem with the interpretation of the value estimates of species preservation is the frequently missing link between the value assigned to a par-

Table 4
Single species valuation surveys

Author(s)	Study	Mean WTP estimates (per household per year)
Stevens et al. (1997)	Restoration of the Atlantic salmon in one river, Massachusetts	$14.38–21.40
Jakobsson and Dragun (1996a)	Conservation of the Leadbeater's Possum, Australia	$29 (Australian $)
Boman and Bostedt (1995)	Conservation of the Wolf in Sweden	700 SEK to 900 SEK
Loomis and Larson (1994)	Conservation of the Gray Whale, US	$16–18
Loomis and Helfand (1993)	Conservation of various single species, US	From $13 for the Sea Turtle to $25 for the Bald Eagle
Van Kooten (1993)	Conservation of waterfowl habitat in Canada's wetlands region	$50–60 (per acre)
Bower and Stoll (1988)	Conservation of the Whooping Crane	$21–141
Boyle and Bishop (1987)	Two endangered species in Wisconsin: the Bald Eagle and the Striped Shiner	From $5 for the Striped Shiner to $28 to the Bald Eagle
Brookshire et al., (1983)	Grizzly Bear and Bighorn Sheep in Wyoming	From $10 for the Grizzly Bear to $16 for the Bighorn Sheep

Table 5
Multiple species valuation surveys

Author(s)	Study	Mean WTP Estimates (per household per year)
Jakobsson and Dragun (1996b)	Preservation of all endangered species in Victoria	$118 (Australian $)
Desvousges et al. (1993)	Conservation of the migratory Waterfowl in the Central Flyway	$59–71
Whitehead (1993)	Conservation program for coastal nongame wildlife	$15
Duffield and Patterson (1992)	Conservation of fisheries in Montana Rivers	$2–4 (for residents) $12–17 (for non residents)
Halstead et al. (1992)	Preservation of the Bald Eagle, Coyote and Wild Turkey in New England	$15
Hampicke et al. (1991)	Preservation of endangered species in West Germany	140–250 DM
Johnansson (1989)	Preservation of 300 endangered species in Sweden	1275 SEK
Samples and Hollyer (1989)	Preservation of the Monk Seal and Humpback Whale	$9.6–13.8
Hageman (1985)	Preservation of threatened and endangered species populations in the US	$17.73–23.95

ticular (set of) species and the area needed to protect (their) habitats. Some studies instead link the value of biodiversity to the value of natural habitat conservation. Some examples are as listed in Table 6. For example, Bateman et al. (1992) undertook a CV study to assess the monetary value of conserving the Norfolk Broads, a wetland site in the UK that covers three National Nature Reserves. The estimation results from a mail survey show that respondents living in a defined 'near-Norfolk Broads' zone had a WTP of 12 lb whereas those living 'elsewhere UK' zone had a WTP of 4 lb.

In the context of the Netherlands, Hoevenagel (1994) asked 127 respondents for an annual contribution to a fund from which farmers in the Dutch meadow region would receive a government grant if they managed their land in a way that enhances wildlife habitat. The average WTP was between 16 and 45 Dutch guilders. Brouwer (1995) found similar results. More recently, Nunes (1999) used for the first time a national CV application in Portugal to assess the WTP for the protection of a Wilderness Area. The mean WTP results ranged from $40 to $51. In the US context, Mitchell and Carson (1984) used the CV method to value the preservation of water ecosystems and aquatic-related benefits provided by all rivers and lakes in the US. Loomis (1989) used CV to value the preservation of the Mono Lake, California (see valuation figures in Table 6). Kealy and Turner (1993) estimated the benefits derived from the preservation of the Adirondack aquatic system. The WTP estimates ranged between $12 and $18. Boyle (1990) valued the preservation of the Illinois beach nature reserve. The estimation results show that the average WTP ranged between $37 and $41. Silberman et al. (1992) studied the existence value of beach ecosystems for users and nonusers of New Jersey beaches. The results show that the mean WTP for a user is about $15.1 while the mean WTP for a nonuser is about $9.26.

Other studies instead link the value of biodiversity to the value of protection of natural areas with high tourism and outdoor recreational demand. At this biodiversity value category, biodiversity has been assessed through various methods, including CV, TC method and market prices such as tourism revenues. Some examples are as listed in Table 7. For example, the World Tourism Organization (WTO, 1997) estimated that Ecuador earned $255 million from ecotourism in 1995. A major sum accrued to a single park, the Galapagos Islands. In Rwanda, gorilla tourism in the Volcanoes National Park generated directed revenues of $1.02 million annually until 1994, or $68 per ha (AG Ökotourismus/ BMZ, 1995).

Studies of less popular parks indicate lower values. The recreational value of Mantadia National Park in Madagascar was estimated to range between $9 and $25 per ha (Mercer et al., 1995). One particularly interesting valuation result is the study by Norton and Southey (1995). This study calculates the economic value of natural habitat for biodiversity protection in Kenya by assessing the associated opportunity costs of foregone agricultural production, which is estimated to be $203 million. This is much higher than the $42 million of net financial revenues from wildlife tourism. Layman et al. (1996) explored the TC method to estimate the recreational fishing value of Chinook salmon in the Gulkana river, Alaska. The estimates of the mean consumer's surplus per day range from $17 to $60 for actual trips, depending upon the wage rate. Choe et al., (1996) estimated the economic benefits of surface water improvements through a public health pollution program at Times Beach in the Philippines. Welfare estimates ranged from $1.44 to $2.04 per trip.

More recently, Chase et al. (1998) studied ecotourism demand in Costa Rica. The value estimates result from the survey of foreign visitors to three national parks: Volcan Irazu, Volcan Poas, and Manuel Antonio. Manuel Antonio national park registered the highest WTP, $24.90. Finally, Moons (1999) used the TC method to assess the economic value recreation activities in the Meerdal-Heverlee forest in Belgium.

Table 6
Natural habitat valuation surveys

Author(s)	Study	Mean WTP estimates (per household)
Nunes (1999)	Protection of wilderness areas, Portugal	$40–51
Wiestra (1996)	Protection of ecological agricultural fields, The Netherlands	Single-bounded: Dfl. 35
Richer (1995)	Desert protection in California, US	$101
Brouwer (1995)	Protection of Peat Meadow Land, The Netherlands	Dfl. 28 to Dfl. 72
Carson et al. (1994)	Protection of the Kakadu Conservation Zone and National Park, Australia	$52 (minor impact scenario), $80 (major impact scenario)
Hoevenagel (1994)	Enhancing wildlife habitat in the Dutch Peat Meadow region, The Netherlands	NLG 16 to NLG 46
Kealy and Turner (1993)	Preservation of the aquatic system in the Adirondack Region, US	$12–18
Hoehn and Loomis (1993)	Enhancing wetlands and habitat in San Joaquin valley in California, US	$96–184 (single program)
Diamond et al. (1993)	Protection of wilderness areas in Colorado, Idaho, Montana, and Wyoming, US	$29–66
Silberman et al. (1992)	Protection of beach ecosystems, New Jersey, US	$9.26–15.1
Bateman et al. (1992)	Protection of the Norfolk Broads, a wetland site, UK	£4–12
Boyle (1990)	Preservation of the Illinois Beach State Nature Reserve, US	$37–41
Loomis (1989)	Preservation of the Mono Lake, California, US	$4–11
Smith and Desvousges (1986)	Preservation of water quality in the Monongahela River Basin, US	$21–58 (for users), $14–53 (for nonusers)
Bennett (1984)	Protection of the Nadgee Nature Reserve, Australia	$27
Mitchell and Carson (1984)	Preservation of water quality for all rivers and lakes, US	$242
Walsh et al. (1984)	Protection of wilderness areas in Colorado, US	$32

Table 7
Tourism and outdoor recreational valuation studies

Author(s)	Study	Measurement method	Estimates
Moons (1999)	Enjoyment received in forest related recreation activities in Flanders, Belgium	Travel cost	1030 BF per trip
Chase et al. (1998)	Protection of the recreation opportunities in three national parks, Costa Rica	Contingent valuation	\$21.60–24.90 per visitor
WTO (1997)	Ecotoursim in Ecuador	Tourism revenue	\$255 million
Layman et al. (1996)	Chinook salmon in the Gulkana river, Alaska	Travel cost	\$17–60 per trip
AG Ökotourismus/BMZ (1995)	Gorilla tourism in the Volcanoes National Park, Rwanda	Tourism revenue	\$1.02 million annually
Choe et al. (1996)	Value of a public health program at the Times Beach, Philippines	Travel cost	\$1.44–2.04 per trip
Mercer et al. (1995)	Recreational value of Mantadia National Park, Madagascar	Tourism revenue	\$9 and 25 per ha
Norton and Southey (1995)	Biodiversity conservation in Kenya	Production function	\$203 million
Pina (1994)	Spending of eco-tourists in Mexico	Travel cost	\$60–100 per day
Tobias and Mendelsohn (1990)	Tourism and ecotourism based on non-consumptive uses of wildlife in Costa Rica	Tourism revenue	\$1.2 million per ha

5.5. Biodiversity, ecosystem functions and ecological services protection

The CV method has been widely used for valuing biodiversity benefits around the world in terms of both species diversity and natural habitat protection. Nevertheless, when it comes to the monetary valuation of ecosystem functions, CV may not always be the first best choice. This is because ecosystem functions, such as ecosystem life support, are not an issue that the general public is familiar with. In addition, the complexity of the relationships involved makes an accurate and comprehensive description in a survey extremely difficult. Researchers frequently end up with the use of valuation methods based on TCs, AB or PFs. A distinction of valuation studies in this context is based on soil and wind erosion, water quality, and wetland ecosystem's functions. These are listed in Table 8.

5.5.1. Soil and wind erosion valuation studies

One category of valuation of ecosystem functions and services relates to soil erosion. Veloz et al. (1985) performed an economic analysis and valuation of soil conservation in the Dominican Republic. They estimate that for a 25-year land use interval the net returns with the introduction of such an erosion control program are about DR\$ 260 per ha. Walker and Young (1986) estimate the damages of soil erosion on (loss of) agriculture revenue in the Palouse region, northern Idaho and western Washington, to be equal to \$4 and \$6 per acre, for a scenario with slow and rapid technological progress, respectively.

Holmes (1988) studied the impact of water turbidity due to soil erosion on the costs of the water treatment industry. Estimates show that the mitigation costs ranged from \$4 to \$82 per million gallons of water for conventional and direct filtration systems, respectively. Applying these estimates to the American Water Works Association figures on the total surface water withdrawn, the nation-wide damages induced by turbidity is estimated to be between \$35 and \$661 million annually.

King and Sinden (1988) explored the HP method in order to capture the value of soil conservation in the farm land market of Manilla Shire, Australia. The hedonic land market price regression results show that the soil condition (e.g. depth of topsoil) has an implicit marginal price of \$2.28 per ha. More recently, Huszar (1989) studied erosion due to the wind in New

Mexico. According to this study, wind erosion costs to households follow from increased cleaning, maintenance and replacement expenditures, and also from reduced consumption and production opportunities. A household cost function was estimated on the basis of 242 survey respondents. The total household costs were estimated to be $454 million per year.

5.5.2. Water quality valuation studies

Water quality has been valued in many studies. Ribaudo (1989a,b) is responsible for one of the most comprehensive studies of valuing water quality benefits. The author valued the economic benefits from a reduction in the discharge of pollutants in waterway systems for nine impact categories: recreational fishing, navigation, water storage, irrigation ditches, water treatment, industrial water use, steam cooling, and flooding. The study targeted all the US territory, which was operationalized in terms of ten regions (Appalachia, Corn Belt, Delta, Lake States, Mountain, Northeast, Northern Plains, Southern Plains, Pacific and Southeast). Benefits were defined in terms of changes in defensive expenditures, changes in production costs, and changes in consumer surplus, depending on the damage category and the availability of data. The total water quality benefits were estimated to be $4.4 billion.

Torell et al. (1990) assessed the market value of water in-storage on the High Plains aquifer, a water ecosystem that underlies parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Water value estimates range from $9.5 per acre-foot in New Mexico to $1.09 per acre-foot in Oklahoma. Abdalla et al. (1992) conducted an economic valuation of contamination of a groundwater

Table 8
Ecosystem functions and services

Author(s)	Study	Measurement method	Estimates
Laughland et al. (1996)	Value of a water supply in Milesburg, Pennsylvania, US	Averting expenditures	$14 and 36 per household
Turner et al. (1995)	Life-support value of a wetland ecosystem in a island of the Baltic Sea, Sweden	Replacement costs	$0.4–1.2 million
Barbier (1994)	Preservation of Hadejia-Jama' are wetlands, Nigeria	Production function	N850–N1280 per ha
Abdalla et al. (1992)	Groundwater ecosystem in Perkasie, Pennsylvania, US	Averting expenditures	$61 313–131 334
McClelland et al. (1992)	Protection of groundwater program, US	Contingent valuation	$7–22
Andreasson-Gren (1991)	Nitrogen purification capacity of a island in the Baltic Sea, Sweden	Replacement costs	SEK 968 per kg
Torell et al. (1990)	Water in-storage on the high plains aquifer, US	Production function	$9.5–1.09 per acre-foot
Ribaudo (1989a,b)	Water quality benefits in ten regions in US	Averting expenditure	$4.4 billion
Huszar (1989)	Value of wind erosion costs to households in New Mexico, US	Replacement costs	$454 million per year
King and Sinden (1988)	Value of soil conservation in the farm land market of Manilla Shire, Australia	Hedonic price	$2.28 per ha
Holmes (1988)	Value of the impact of water turbidity due to soil erosion on the water treatment, US	Replacement costs	$35–661 million annually
Walker and Young (1986)	Value of soil erosion on (loss) agriculture revenue in the Palouse region, US	Production function	$4 and 6 per acre
Veloz et al. (1985)	Soil erosion control program in a watershed, Dominican Republic	Production function	DR$ 260 per ha

ecosystem in Perkasie, Pennsylvania. The study was conducted with the help of a household survey that asked information about respondents' expenditures since December 1987, the time when the contamination was first detected. The average weekly increase in averting expenditures per household that undertook averting actions in response to contamination was $0.40. The costs of these actions, when extrapolated to the total population of Perkasie residents, ranged from $61 313 to $131 334, depending on the wage rate used to reflect the value of lost leisure time.

More recently, Laughland et al. (1996) assessed the economic value of water supply in Milesburg, also in Pennsylvania. The author used cost savings with two alternative values of time and the CV method. The mean averted cost range between $14 and $36, using family income and using the minimum wage to value time, respectively.

5.5.3. *Wetland ecosystem's functions valuation studies*

Andreasson-Gren (1991) estimated the benefit of nitrogen abatement due to wetland restoration by estimating the replacement costs for conventional nitrogen abatement technologies. The nitrogen purification capacity of wetlands was estimated for Gotland, a Swedish island in the Baltic Sea. According to the study's results, the total value of a marginal increase in nitrogen abatement by Gotland was about SEK 968 per kg. Barbier (1994) conducted a value assessment of the Hadejia-Jama' area wetlands, Nigeria, by focusing on the opportunity costs of its loss. The valuation analysis covered direct use values of the floodplain to the local population through crop production, fuelwood and fishing. The present value of the aggregate stream of such benefits was estimated to be in the range of 850–1280 Naire per ha. Turner et al. (1995) addressed the problem of valuation of wetland ecosystems. This study also attempted to break down direct and indirect value into a much finer set of categories. Their valuation, based on Folke (1991), refers to the assessment of the life-support value of Martebo, a wetland ecosystem in the Swedish island in the Baltic Sea. An annual monetary estimate of the replacement cost was derived from information about the amount of industrial energy needed to substitute for the loss of wetland-produced goods and services.

6. Discussion of the valuation results

From the review of the economic valuation studies, it is clear that the assessment of biodiversity values does not lead to a univocal, unambiguous monetary indicator. Indeed, the range of monetary estimates of biodiversity values is expected to depend on the level of life diversity under consideration, the biodiversity value type under assessment, as well the selection of the valuation method. A summary of the various combinations of possible elements is presented in Table 9).

At the most basic level of life diversity, the market value of bioprospecting contracts signed between the pharmaceutical and agriculture industries and governmental agencies sheds some light on the economic value of genetic diversity. However, these industries, WTP only considers the potential impact of genetic diversity through the use of plant and animal material in the development of new medicines and new products. Indirect, existence, and moral values of genetic diversity are not included in the contract market value. Therefore, and at the best, these contracts should be interpreted as providing lower bounds of the economic value of genetic diversity changes. A more extreme position is adopted by some environmental groups, which interpret these market agreements as unequivocal biopiracy actions that cannot serve as the basis for genetic diversity values. Alternatively, one can pursue economic valuation of biodiversity at the species level. Application of economic valuation to species diversity can be operationalized in terms of single and multiple species studies. The respective value range estimates are characterized by a high degree of uncertainty. For example, the WTP in multiple species studies is higher than in single species studies, though not so high as one would initially expect. This reflects not only the complexity of accurately assessing species distinctions, and genetic distances, but also the difficulty in dealing

Table 9
Synthesis

Life diversity level	Biodiversity value type	Value ranges	Method(s) selected
Genetic and species diversity	Bioprospecting	From $175 000 to $3.2 million	Market contracts
	Single species	From $5 to 126	Contingent valuation
	Multiple species	From $18 to 194	Contingent valuation
Ecosystems and natural habitat diversity	Terrestrial habitat (non-use)	From $27 to 101	Contingent valuation
	Coastal habitat (non-use)	From $9 to 51	Contingent valuation
	Wetland habitat (non-use)	From $8 to 96	Contingent valuation
	Natural areas habitat (recreation)	From $23 per trip to 23 million per year	Travel cost, tourism revenues
Ecosystems and functional diversity	Wetland life-support	From $0.4 to 1.2 million	Replacement costs
	Soil and wind erosion protection	Up to $454 million per year	Replacement costs, hedonic price, production function
	Water quality	From $35 to 661 million per year	Replacement costs, averting expenditure

with substitutability of species. If, for example, a single species valuation study fails to consider in an adequate way that other species are possible substitutes then single, it may have limited relevance for the valuation of the species diversity. Nevertheless, recent research efforts focusing at the improvement of the methods for economic valuation, especially after the NOAA panel recommendations for CV have contributed to a more accurate survey design. CV can thus contribute to the assessment of economic values of species diversity.

Some economic valuation studies focus on higher organization levels of biodiversity. Important biodiversity value types were identified, notably, biodiversity values related to natural habitat, ecosystem functions and ecological services protection. Biodiversity values of natural habitats generate both use and nonuse value options due to the protection of recreation and wilderness areas. CV continues to be a preferred valuation method since it is the only one that can assess the magnitude of nonuse values, such as the existence value of the knowledge that the natural habitats, and its wildlife diversity, is kept free from commercial development and closed to visitors. TC method and tourism revenues, based on market prices, constitute important alternatives to the CV method whenever the valuation study focuses on biodiversity values related to recreational values, such as sightseeing.

Using CV is problematic when the objective is to elicit the economic value of changes in biodiversity following from changes in biochemical and ecosystem processes that are far removed from human perceptions, such as CO_2 storage or groundwater purification processes. In this case, the degree of uncertainty surrounding the value estimates will be very high. The complexity and variety of interrelationships in which species exist in different ecosystems, the functions among ecosystems, as well as their capacity to deal with disturbances, should be taken into account. In other words, the valuation study needs to consider a wide range of indirect or primary biodiversity values. This is surely not an easy task. The difficulty will be magnified when a larger geographical area of analysis is used. In addition, the complexity increases if larger changes are studied. Without any doubt, a full monetary assessment will then be impossible or subject to much scientific debate. Therefore, it is nonsense to try to value extremely large changes in biodiversity, and certainly extremes ones like valuation of all the biodiversity in the world.

A possible strategy to attain a global value has been to adopt a bottom-up approach, aggregating local values of different studies. Economics starts from the assumption that social values are based in individual values. Special attention, however, is required when aggregating valuation studies so as to cope with different socio-economic contexts. One has to correct for different income distributions, and avoid double counting, e.g. correct for possible substitution effects across a variety of biodiversity-ecosystem-ecological relationships.

All in all, present economic valuation studies of biodiversity, at the different life levels and value types, should be critically regarded and respective estimates are at best considered as lower bounds to (yet) unknown values of biodiversity, and always contingent upon the available scientific information as well as the global socio-economic context.

7. Conclusions

Biodiversity is a complex, abstract concept. It can be associated with a wide range of benefits to human society, most of them still ill understood. In general terms, the value of biodiversity can be assessed in terms of its impact on the provision of inputs to production processes, in terms of its direct impact on human welfare, and in terms of its impact on the regulation of the nature-ecosystem-ecological functions relationships. Usually, market valuation mechanisms that price the value of biodiversity are lacking. Therefore, valuation of biodiversity requires the use of special valuation tools. This article has reviewed some economic valuation studies of biodiversity. Monetary valuation of changes of biodiversity involves crucial choices with respect to: (a) the level of life diversity; (b) the biodiversity value category; (c) the most appropriate valuation method, and (d) the overall perspective on the value of biodiversity. The main conclusion is that monetary valuation of changes of biodiversity can make sense. This requires, inter alia, that a clear life diversity level is chosen, that a concrete biodiversity change scenario is formulated, that a multidisciplinary approach seeking the identification of direct and indirect effects of the biodiversity change on human welfare is used, and, very importantly, that the change is well defined and not too large. So far, relatively few valuation studies have met all these requirements. As a matter of fact, from the review of the economic valuation studies it is clear that the assessment of biodiversity values does not lead to a univocal, unambiguous monetary indicator. Nevertheless, prudent interpretation of the monetary valuation results can shed some light on the value of biodiversity, leading to lower bounds.

Acknowledgements

This research was funded by the Priority Program on 'Sustainable Use and Conservation of Marine Living Resources' of the Netherlands Organization for Scientific Research (NWO). Wim Wolff and two anonymous referees have provided valuable comments on an earlier draft of this article. Paula Nunes acknowledges the Fundação Calouste Gulbenkian for financial support.

References

Abdalla, C.W., Roach, B.A., Epp, D.J., 1992. Valuing environmental quality changes using averting expenditure: an application to groundwater contamination. Land Economics 38 (2), 163–169.

AG Ökotourismus/BMZ, 1995. Ökotourismus als Instrument des Natuurschutzes? Forschungsberichte des BMZ, München, value cited in Gössling, S., 1999. Ecotourism: a means to safeguard biodiversity and ecosystem functions? Ecological Economics 29, 303–320

Andreasson-Gren, I.M., 1991. Costs for Nitrogen source reduction in a eutrophicated bay in Sweden. In: Folke, C., Kaberger, T. (Eds.), Linking the Natural Environment and the Economy: Essays from the Eco-group. Kluwer Academic Publishers, Dordrecht.

Arnett, R.H., 1985. General considerations. In: American Insects: a Handbook of the Insects of America North of Mexico. Van Nostrand Reinhold, New York, pp. 3–9.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C., Pimemtel, D., 1995. Economic growth, carrying capacity, and the environment. Science 4, 13–28.

Barbier, E.B., 1994. Valuing environmental functions: tropical wetlands. Land Economics 70 (2), 155–173.

Bateman, I.J., Willis, K.G., Garrod, G.D., Doktor, P., Langford, I., Turner, R.K., 1992. Recreation and environmental preservation value of the Norfolk broads: a contingent valuation study, report to the national rivers authority, environmental appraisal group, University of East Anglia, valuation results cited in Turner et al., 1995.

Bennett, J.W., 1984. Using direct questioning to value the existence benefits of preserved natural areas. Australian Journal of Agricultural Economics 28, 136–152.

Boman, M., Bostedt, G., 1995. Valuing the wolf in Sweden, Report No. 110, Swedish University of Agricultural Sciences, Department of Forest Economics, Umeä.

Bonalume, N., Dickson, D., 1999. $3m deal launches major hunt for drug leads in Brazil. Nature 400 (6742), 302 22 July.

Bower, J.M., Stoll, J.R., 1988. Use of dichotomous choice nonmarket methods to value the whooping crane resource. American Journal of Agricultural Economics 70, 327–381.

Boyle, K.J., 1990. Dichotomous choice, contingent valuation questions: functional form is important. Northeastern Journal of Agriculture and Resource Economics 19 (2), 125–131.

Boyle, K.J., Bishop, R.C., 1987. Valuing wildlife in benefit-cost analysis: a case study involving endangered species. Water Resources Research 23, 943–950.

Braden, J.B., Kolstad, C.D. (Eds.), 1991. Measuring the Demand for Environment Quality. Elsevier, North-Holland.

Brookshire, D.S., Eubanks, L.S., Randall, A., 1983. Estimating option prices and existence values for wildlife resources. Land Economics 59, 1–15.

Brouwer, R., 1995. The measurement of the non-marketable benefits of agricultural wildlife management: the case of Dutch peat meadow land, Wageningen economic papers, University of Wageningen, Wageningen, The Netherlands.

Carson, R.T., Wilks, L., Imber, D., 1994. Valuing the preservation of Australia's Kakadu conservation zone Oxford economic papers. Oxford 46 (5), 727–749.

Carson, R., 1997. Contingent valuation surveys and tests of insensitivity to scope. In: Kopp, R.J., et al. (Eds.), Determining the Value of Non-Marketed Goods. Kluwer Academic Publishers, The Netherlands Chapter 6.

Chase, L.C., Lee, D.R., Schulze, W.D., Anderson, D.J., 1998. Ecotourism demand and differential pricing of national park access in Costa Rica. Land Economics 74 (4), 466–482.

Choe, K., Whittington, D., Lauria, D.T., 1996. The economic benefits of surface water quality improvements in developing countries: a case study of Davos, Philippines.

Cragg, G.M., Newman, D.J., Yang, S.S., 1998. Bioprospecting for drugs. Nature 393 (6683), 301 28 May.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1998. The value of the world's ecosystem services and natural capital. Ecological Economics 25, 3–15.

Desvousges, W.H., Johnson, F.R., Dunford, R.W., Boyle, K.J., Hudson, S.P., Wilson, K.N., 1993. Measuring natural resource damages with contingent valuation: tests of validity and reliability, In: Hausman, J.A. (ed.), Contingent valuation: a critical assessment, contributions to economic analysis, Chapter III, North-Holland, New York, US.

Diamond, P.A., Hausman, J.A., Leonard, G.L., Denning, M.A., 1993. Does contingent valuation measure preferences? experimental evidence, In: Hausman, J.A. (ed.), Contingent valuation: a critical assessment, contributions to economic analysis, Chapter II, North-Holland, New York, US.

Duffield, J.W., Patterson, D.A., 1992. Field testing existence values: an instream flow trust fund for Montana Rivers, paper presented at the Allied Social Science Association Annual Meeting, New Orleans, Louisiana.

Ehrenfeld, D., 1988. Why put a value on biodiversity. In: Wilson, E.O. (Ed.), Biodiversity. National Academy Press, Washington, DC.

Farnworth, E.G., Tidrick, T.H., Jordan, C.F., Smathers, W.M., 1981. The value of ecosystems: an economic and ecological framework. Environmental Conservation 8, 275–282.

Faber, M., Manstetten, R., Proops, J., 1996. Ecological Economics. Concepts and Methods. Edward Elgar, Cheltenham, Brookfield.

Folke, C., 1991. The societal value of wetland life support. In: Folke, C., Kaberger, T. (Eds.), Linking the Natural Environment and the Economy: Essays from the Eco-group. Kluwer Academic Publishers, Dordrecht.

Folke, C., Holling, C.S., Perrings, C., 1996. Biological diversity, ecosystems and the human scale. Ecological Applications 6, 1018–1024.

Fromm, O., 2000. Ecological structure and functions of biodiversity as elements of its total economic value. Environmental and Resource Economics 16, 303–328.

Gowdy, J.M., 1997. The value of biodiversity: markets, society and ecosystems. Land Economics 73 (1), 25–41.

Gren, I.-M., Folke, C., Turner, R.K., Bateman, I., 1994. Primary and secondary values of wetland ecosystems. Environmental and Resource Economics 4, 55–74.

Grifo, F., Newman, D., Fairfield, A.S., Bhattacharya, B., Grupenhoff, J.T., 1996. The origins of prescription drugs. In: Grifo, F., Rosenthal, J. (Eds.), Biodiversity and Human Health. Island Press, Washington.

Hageman, R., 1985. Valuing marine mammal populations: benefits valuations in multispecies ecosystems, In: Administrative Report, Southwest Fisheries, values cited in Eagle, J., Betters, D., 1998. The Endangered Species Act and

Economic Values: a Comparison of Fines and Contingent Valuation Studies, Ecological Economics 26, 165–171.

Halstead, J.M., Luloff, A.E., Stevens, T.H., 1992. Protest bidders in contingent valuation. Northeastern Journal of Agricultural and Resource Economics 21 (2), 247–361.

Hammond, D.L., Ricklefs, R.E., Cowling, R.M., Samways, M.J., 1995. Magnitude and distribution of biodiversity. In: Global Biodiversity Assessment, UNEP, pp. 21–106.

Hampicke, U., Tampe, K, Kiemstedt, K., Horlitz, H., Walters, U., Timp, D., 1991. The economic Importance of preserving Species and Biotopes in the Federal Republic of Germany, results cited in Romer, A.U., Pommerehne, W.W., 1992. Germany and Switzerland. In Navrud (Ed.). Pricing the European Environment, Scandinavian University Press.

Hoehn, J.P., Loomis, J.B., 1993. Substitution effects in the valuation of multiple environmental programs. Journal of Environmental Economics and Management 25 (1), 56–75.

Hoevenagel, R., 1994. The contingent valuation method: scope and validity, Ph.D. dissertation, Institute for environmental studies, Vrije Universiteit, Amsterdam.

Holling, C.S., 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4, 1–23.

Holling, C.S., Schindler, D.W., Walker, B.W., Roughgarden, J., 1995. Biodiversity in the functioning of ecosystems: an ecological synthesis. In: Perrings, C., et al. (Eds.), Biodiversity Loss: Economic and Ecological Issues. Cambridge University Press, Cambridge, MA.

Holmes, T.P., 1988. The offsite impact of soil erosion on the water treatment industry. Land Economics 64 (4), 356–366.

Huszar, P.C., 1989. Economics of reducing off-site costs of wind erosion. Land Economics 65 (4), 333–340.

INBio-Instituto Nacional de Biodiversidad, 2001., Biodiversity Prospecting, accessed online at http://www.inbio.ac.cr/en/pdb/Prosp.html.

Johnansson, P.-O., 1989. Valuing public goods in a risky world: an experiment. In: Folmer, H., Ierland, E. (Eds.). Evaluation Methods and Policy Making in Environmental WI Economics, Amsterdam, North Holland.

Johnson, K.H., Vogt, K.A., Clark, O.J., Schmitz, Vogt, D.J., 1996. Biodiversity and the productivity and stability of ecosystems, Trends in Ecology and Evolution, 11, pp. 372–377.

Jakobsson, K.M., Dragun, A.K., 1996a. Contingent Valuation and Endangered Species. Edward Elgar, UK, p. 269.

Jakobsson, K.M., Dragun, A.K., 1996b. The economics of endangered species, working-paper of Swedish University Agricultural Sciences presented at the 7th Annual Conference of the EAERE.

Kealy, M.J., Turner, R.W., 1993. A test of the equality of the closed-ended and the open-ended contingent valuations. American Journal of Agriculture Economics 75 (2), 311–331.

King, D.A., Sinden, J.A., 1988. Influence of soil conservation on farm land values. Ecological Economics 64 (3), 242–255.

Laughland, A.S., Musser, W.N., Shortle, J.S., Musser, L.M., 1996. Construct validity of averting cost measures of environmental benefits. Land Economics 72 (1), 100–112.

Layman, R.C., Boyce, J.R., Criddle, K.R., 1996. Economic value of Chinook Salmon Sport Fishery of the Gulkana river, Alaska, under current and alternative management plans. Land Economics 72 (1), 113–128.

Loomis, J.B., 1989. Test-retest reliability of the contingent valuation method: a comparison of general population and visitor responses. American Journal of Agriculture Economics 71 (1), 76–84.

Loomis, J.B., Helfand, G., 1993. A tale of two owls and lessons for the reauthorization of the endangered species act, Choices, 21–25.

Loomis, J.B., Larson, D.M., 1994. Total economic value of increasing Gray Whale populations: results from a contingent valuation survey of visitors and households. Marine Resource Economics 9, 275–286.

Macilwain, C., 1998. Bid to block yellowstone enzymes deal. Nature 392 (6672), 117 12 March.

Mäler, K.-B., 1988. Production function approach in developing countries, In: Vincent et al. (eds.). Valuing Environmental Benefits in Developing Countries, Special Report, Michigan State University, pp. 11–32.

McClelland, G.H., Schulze, W.D, Lazo, J.K., Waldman, D.M., Doyle, J.K., Elliot, S.R. and J.R. Irwin, 1992. Methods for measuring the non-use values: a contingent valuation study of the groundwater cleanup, draft report to USEPA, Center for Economic Analysis, University of Colorado, Boulder, Colorado.

Mercer, E., Kramer, R., Sharma, N., 1995. Rainforest tourism: estimating the benefits of tourism development in a new national park in Madagascar. Journal of Forest Economics 1 (12), 239–269.

Miller, K.R., Furtado, J., Klemm, C., McNeely, J.A., Myres, N., Soule, M.E., Texton, M.C., 1985. Maintaining biological diversity, the key factor for a sustainable society, IUCN, Gland.

Mitchell, R.C., Carson, R.T., 1984. Willingness to pay for national freshwater improvements, draft report to USEPA, Resources for the Future, Washington, DC.

Moons, E., 1999. Estimation of the recreation values of a forest, M.Sc. dissertation, Faculty of economics and applied economics, Catholic University of Leuven.

Myers, N., 1988. Threatened biotas: hot-spots in tropical forests. Environmentalist 8, 187–208 n.3.

NOAA-National Oceanic and Atmospheric Administration, 1993. Report of the NOAA Panel on Contingent Valuation, Federal Register US, 58(10), pp. 4601–4614.

Norton, B.G., 1986. On the inherent danger of undervaluing species. In: Norton, B.G. (Ed.), The preservation of species. Princeton University Press, Princeton.

Norton, G.M., Southey, C., 1995. The opportunity costs of biodiversity protection in Kenya. Ecological Economics 11, 135–151.

Norton, G.M., Ulanowicz, R.E., 1992. Scale and biodiversity policy: a hierarchical approach. Ambio 21 (3), 244–249.

Nunes, P.A., 1999. Contingent valuation of the benefits of natural areas and its warm glow component Ph.D. dissertation, Faculty of Economics and Applied Economics, Catholic University of Leuven; forthcoming as The Contingent Valuation of National Parks: Assessing the Warm Glow Propensity Factor, Edward Elgar Publishing, Camberley, UK.

Odum, H.T., 1950. Bird populations of the Highlands Plateau in relation to plant succession and avian invasion. Ecology 31, 587–605.

Parker, S.P., 1982. (Ed.) Synopsis and Classification of Living Organisms, New York: MacGraw-Hill, 2 vols.

Pearce, D., 1999. Valuing biological diversity: issues and overview, draft paper presented at OECD workshop on benefit valuation for biodiversity resources, 1999.

Pearce, D., Moran, D., 1994. The Economic Value of Biodiversity. Earthscan Publications Limited, London, UK.

Perrings, C., Pearce, D., 1994. Threshold effects and incentives for conservation of biodiversity. Environmental and Resource Economics 4, 13–28.

Pimm, S.G.R., Gittleman, J., Brooks, T., 1995. The future of biodiversity. Science 269, 347–350 21 July.

Pina, C.M., 1994. Cited in Jakobsson and Dragun (1996b). The economics of endangered species, working-paper, Swedish University Agricultural Sciences presented at the 7th Annual Conference of the EAFRE.

RAFI – Rural Advancement Foundation International, 2001. Bioprostecting/Biopiracy and indigenous peoples, online at http://www.latinsynergy.org/bioprospecting.htm.

Randall, A., 1988. What mainstream economists have to say about the value of biodiversity. In: Wilson, E.O. (Ed.), Biodiversity. National Academy Press, Washington, DC.

Ribaudo, M.O., 1989a. Water quality benefits from the conservation reserve program, agricultural economics report, Economic Research Service, Washington.

Ribaudo, M.O., 1989b. Targeting the conservation reserve program to maximize water quality benefits. Land Economics 65 (4), 320–332.

Richer, J., 1995. Willingness to pay for desert protection. Contemporary Economic Policy XIII, 93–104.

Samples, K., Hollyer, J., 1989. Contingent valuation of wildlife resources in the presence of substitutes and complements, In: Johnson, R., Johnson, G. (Eds.). Economic Valuation of Natural Resources: Issues, Theory and Application, Boulder.

Silberman, J., Gerlowski, D.A., Williams, N.A., 1992. Estimating existence value for users and nonusers of New Jersey beaches. Land Economics 68 (2), 225–236.

Simon, H., Wildavsky, A., 1995. Species lost revisited. In: Simon, J. (Ed.), The State of Humanity. Blackwell, Oxford, pp. 346–362.

Simpson, R., Sedjo, R.A., Reid, J.W., 1996. Valuing biodiversity for use in pharmaceutical research. Journal of Political Economy 101, 163–185.

Smith, V.K., Desvousges, W.H., 1986. Measuring Water Quality Benefits. Kluwer Nijhoff Publishing, Dordrecht.

Sonner, S., 1998. Suit Tries to Block 'Bioprospecting' in Yellowstone, Idaho News, 6 March 1998, online at http://www.idahonews.com/030698/A_SECTIO/14974.htm.

Stevens, T.H., DeCoteau, N.E., Willis, C.E., 1997. Sensitivity of contingent valuation to alternative payment schedules. Land Economics 73 (1), 140–148.

Tobias, D., Mendelsohn, R., 1990. Valuing ecotourism in a tropical rain forest reserve. Ambio 20 (2), 91–93.

ten Kate, K., Laird, S., 1999. The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit-Sharing, Earthscan, London.

Torell, L.A., Libbin, J.D., Miller, M.D., 1990. The market value of water in the Ogalla Aquifer. Land Economics 66 (2), 163–175.

Turner, R.K., Folke, C., Gren, I.M., Bateman, I.J., 1995. Wetland valuation: three case studies. In: Perrings, C., Maler, K-G., Folke, C., Holling, C.S., Jansson, B.-O. (Eds.), Biodiversity Loss: Economic and Ecological Issues. Cambridge University Press, Cambridge, MA.

Turner, R.K., Button, K., Nijkamp, P. (Eds.), 1999. Ecosystems and Nature: Economics, Science and Policy, Elgar.

Turner, R.K., van den Bergh, J.C.J.M., Soderqvist, T., Barendregt, A., van der Straaten, J., Maltby, E., van Ierland Ekko, C., 2000. Ecological-economic analysis of wetlands: scientific integration for management and policy. Ecological Economics 35, 7–23.

UNEP – United Nations Environment Program, 1992. Rio Declaration, World Conference on Environment and Development, United Nations Environment Program, Brazil.

van Kooten, G.C., 1993. Bioeconomic evaluation of government agricultural programs on wetland conservation. Land Economics 69 (1), 27–38.

van Kooten, G.C., Bulte, E.H., 2000. The Economics of Nature. Blackwell, UK.

Veloz, A., Southgate, D., Hitzhusen, F., Macgregor, R., 1985. The economics of erosion control in a subtropical watershed: a Dominican case. Land Economics 61 (2), 145–155.

Walker, D.J., Young, D.L., 1986. The effect of technical progress erosion damage and economic incentives for soil conservation. Land Economics 62 (1), 83–93.

Walsh, R.O., Loomis, J.B., Gillman, R.A., 1984. Valuing option, existence, and bequest demands for wilderness. Land Economics 60, 14–29.

Whitehead, J.C., 1993. Total economic values for coastal and marine wildlife: specification, validity and valuation issues. Marine Resource Economics 8, 119–132.

Whittaker, R.H., 1960. Vegetation of the Siskiyou mountains, Oregon and California. Ecological Monographs 30, 279–338.

Whittaker, R.H., 1972. Evolution and measurement of species diversity. Taxon 21, 1–67.

Wiestra, E., 1996. On the domain of contingent valuation, Ph.D. dissertation, Twente University, Twente University Press.

Wilson, E.O., 1988. The current state of biological diversity. In: Wilson, E.O. (Ed.), Biodiversity. National Academy Press, Washington, DC.

Wilson, E.O., 1994. The fundamental unit. In: The Diversity of Life, UK: Penguin. Penguin Group, UK, pp. 33–46.

WTO – World Tourism Organization, 1997. Statistical Year Book of Tourism. World Tourism Organization, Madrid.