Capturing the complexity of biodiversity: A critical review of economic valuation studies of biological diversity

Bartosz Bartkowski[a] (corresponding author), Nele Lienhoop[a], Bernd Hansjürgens[a]

[a] UFZ – Helmholtz Centre for Environmental Research, Permoserstraße 15, D-04318 Leipzig, Germany

Phone number: +49 341 235 1729

E-mail addresses: bartosz.bartkowski@ufz.de, nele.lienhoop@ufz.de, bernd.hansjuergens@ufz.de

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Abstract

Biodiversity is a highly complex and abstract ecological concept. Even though it is not one physical entity, it influences human well-being in multiple ways, mostly indirectly. While considerable research effort has been spent on the economic valuation of biodiversity, it remains to be a particularly challenging 'valuation object'. Valuation practitioners therefore have to use proxies for biodiversity, many of which are very simple (single species, habitats). This paper presents a comprehensive and critical review of biodiversity valuation studies with special emphasis on bio<u>diversity</u> valuation in order to depict the state-of-the-art in this research field. It develops evaluation criteria so as to identify best-practice applications and shows that the field of biodiversity valuation studies is rather heterogeneous regarding both valuation objects and valuation methods. On the basis of our evaluation criteria and best-practice studies we suggest that to account for the complexity and abstractness of biodiversity, multi-attribute approaches with encompassing information provision should be used that emphasise the roles biodiversity plays for human well-being.

Highlights

- Many proxies used in economic valuation fail to grasp the diversity aspect of biodiversity.

- Most studies use single-attribute proxies, which do not reflect the multi-dimensional complexity of biodiversity.
- Multi-attribute proxies are better suited to account for biodiversity, but they are at the minority.
- The emphasis on biodiversity roles with respect to human well-being should be imperative.
- Provision of encompassing information, e.g. via deliberative approaches, is crucial.

Keywords

Biodiversity, Economic valuation, Literature review, Biodiversity proxies, Multi-attribute valuation

1 Introduction

The term biodiversity has experienced a rarely seen rise in recent decades. Coined in 1986 by Walter Rosen, in 1992 it was included in the title of one major outcome of the Rio Earth Summit—the Convention on Biological Diversity. Another 10 years later it was an essential part of the Millennium Ecosystem Assessment framework. Since then, it has been becoming ever more popular both in policy and scientific debates. In 2008, the TEEB (The Economics of Ecosystems and Biodiversity) process was initiated. In 2013, the IPBES, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services was launched, a UN funded body that is hoped to mimic the success and influence the IPCC has in the area of climate change.

Despite its obvious success, or maybe just because of it, the concept of biodiversity has remained vague and thus controversial. Also, its diffusion from scientific discourse into public awareness has been only partial—according to public opinion polls, many people around the world do not know the term, and even fewer are able to define it (DEFRA, 2007; UEBT, 2013). This is not surprising given that biodiversity is a complex, multi-level concept, which includes genetic, species, functional, molecular and phylogenetic diversity, among others. Accordingly, there are many different approaches to the measurement of biodiversity, which reflect various perspectives and specific research needs.

As indicated by the explicit inclusion of the concept in the name of the major study of the state of the art in environmental economics, the first TEEB report on ‘Ecological and Economic Foundations’ (Kumar, 2010), biodiversity is by no means a new concept for economists. On the contrary, economists have made significant contributions to the topic, including, among other things, the design of diversity indices (Solow et al., 1993; Weitzman, 1992; see also Baumgärtner, 2007), models of optimal conservation strategies (Figge, 2004; Weitzman, 1998), analysis of biodiversity as insurance (Weitzman, 2000) and of the socio-economic drivers of biodiversity loss (Swanson, 1998), as well as economic valuation of biodiversity (Heal, 2000; Kumar, 2010; Pearce and Moran, 1994). However, just as in the political discourse, the use of the word ‘biodiversity’ has not always been precise in the economic literature. Often the term is used just as a synonym for ‘nature’ or ‘life on Earth’, which is the *broad meaning* of the word. In its *narrower, more specific meaning*, however, 'bio*diversity*' emphasises the diversity or variety of all the biotic components the ecosphere consists of (Swingland, 2013), rather than the components as such. There is a need to distinguish between the two interpretations of the term.

In the case of valuation, the issue of the term's interpretation might be even more problematic. In fact, economic valuation of nature is mostly based on the ecosystem services approach (Daily, 1997). There are many different frameworks, classifications and definitions of ecosystem services in the valuation context (see, e.g., de Groot et al., 2010, 2002), and no consensus on a common framework has yet been reached (Nahlik et al., 2012). Within the ecosystem services framework(s), the role of biodiversity is at best unclear, allowing for many contesting interpretations, e.g., in respect to the question whether biodiversity is regarded as the source of ecosystem services or not (Atkinson et al., 2012; Elmqvist et al., 2010; Mace et al., 2012). As it is a complex concept rather than a single physical entity, biodiversity cannot be captured 'directly', but only by use of proxies or indicators. Accordingly, economic valuation studies that aim to assign a value to bio*diversity* choose very diverging approaches and use different proxies to approximate this inherently abstract and complex concept (Meinard and Grill, 2011).

Already in the early stages of biodiversity valuation research, Pearce (2001) complained that most valuation studies claiming to provide value estimates of biodiversity actually had valued biological resources, not their *diversity* (see also Turner et al., 2003; Christie et al., 2006). Nunes et al. (2003) and Christie et al. (2004) have reached similar conclusions in their overview of suitable valuation approaches and monetary value estimates for different aspects of biodiversity (genetic and species diversity, single species, multiple species, natural habitats, biological resources, ecosystem functions and services).

Only three studies have reviewed the biodiversity valuation literature (Bakhtiari et al., 2014; Christie et al., 2004; Nunes and van den Bergh, 2001), which differ from the review presented here. Due to their specific focus, the existing reviews explicitly do not include all biodiversity valuation studies available at the time of publication (Christie et al., 2004; Nunes and van den Bergh, 2001) or they focus on a specific class of valuation methods, namely Choice Experiments (Bakhtiari et al., 2014). In our review we provide an update of existing biodiversity valuation studies and include the entire range of valuation methods used. Also, Nunes and van den Bergh's categorisation of biodiversity studies was based deductively on the values they ascribed to biodiversity. Conversely, our approach is more inductive, in that our biodiversity proxies (see section 3) are derived from the studies reviewed here. Furthermore, earlier reviews do not clearly distinguish between biodiversity and biological resources. Here, we argue that this distinction is crucial and assess the accumulated body of valuation research focusing on biodiversity as valuation object. For this purpose, we conducted a comprehensive, exhaustive and critical review of all biodiversity valuation literature available through October 2014 and identified all studies that value diversity.

The specific objectives of the review are:

- to identify and critically discuss the suitability of proxies for biodiversity used in valuation studies;
- to explore common patterns and differences in the relevant body of applied literature;
- to pinpoint strengths and limitations of existing approaches and identify best-practice studies;
- to present criteria for a proper valuation of biodiversity;
- to offer an orientation as to how biodiversity should be valued.

The remainder of our article is structured as follows: in section 2, an overview of the relevant ecological concepts regarding the definition and measurement of biodiversity is offered. The third section discusses the materials and methods used to conduct the actual literature review. We present the categories of biodiversity proxies derived from our review and used to group the approaches found in the studies reviewed. In the fourth section, we outline our understanding of the term 'biodiversity' and delineate it from related valuation objects, and we derive criteria for proper economic valuation of biodiversity. In the fifth section, key results of the review are presented. Section 6 contains an evaluation of the approaches identified in the review in accordance with the criteria proposed in section 4, and the identification and presentation of best-practice approaches. The last, concluding section offers an orientation towards a more consistent framework for the valuation of bio*diversity* and recommendations for future research.

2 Definitions and measures of biodiversity

There exist many different definitions of biodiversity (DeLong, 1996). The term was coined by Walter Rosen in 1986 in the context of the National Forum on BioDiversity (Takacs, 1996). However, its full form, biological diversity, has been in use since at least 1980 (Swingland, 2013). According to critics, the term is not scientific, but advocative (Takacs, 1996), and represents a very vague, "pseudocognate"[1] concept (Gaston, 1996a; see also Kahn et al., 2001). Accordingly, the most widely-used definition of biodiversity, adopted by the Convention on Biological Diversity (CBD, 1992), is not very specific:

> *"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.*

It has been argued, however, that this vagueness is insurmountable, and that for pragmatic reasons it is actually necessary, since the concept is used in many different contexts (Mace et al., 2012; Koricheva and Siipi, 2004). In the end, biodiversity may be viewed as a broad social concept in need for more concrete sub-concepts to be used as proxies when it comes to specific applications.

As a consequence of the term's complexity, abstractness and the insurmountable difficulty to provide an unambiguous definition of it, there exist a vast number of biodiversity measures and indicators (CBD, 2011; Pereira et al., 2013). For every biodiversity level (intraspecies, interspecies, between ecosystems), many different measures are available (see Table 1).

Table 1 Common measures of biodiversity

[1] „Pseudocognate" terms are observed to be implicitly treated as if everyone understood them equally, even though no clear definition exists.

Level of diversity	Measures
Genetic diversity	▪ Allelic diversity (genotypic differences)
Species diversity	▪ Shannon entropy (a.k.a. Shannon-Wiener index) ▪ Gini-Simpson index ▪ Species richness
Phylogenetic/taxonomic/functional	▪ Rao's quadratic entropy ▪ Phylogenetic entropy
Ecosystem diversity	▪ Various similarity indices, mostly based on species diversity indices
Compiled from Magurran (1996), Gotelli and Chao (2013) and Pereira et al. (2013).	

The design and use of biodiversity indices faces essential data constraints (Mace, 2014; Pereira et al., 2013), which may be the reason why in applications species richness and related measures are by far the most popular. Often, less direct indicators of biodiversity (change) are used, including Red List data, habitat amount, water quality for aquatic biodiversity, so-called indicator species etc. (Butchart et al., 2010).

3 Materials and methods

To make the present literature review as comprehensive and exhaustive as possible, all relevant sources have been examined. The following databases were searched for peer-reviewed articles published through October 2014 using a range of alternative search terms for both "biodiversity" and „economic valuation": 1) the Web of Science database , 2) the TEEB Valuation Database (Van der Ploeg and de Groot, 2010), and 3) Carson's contingent valuation bibliography (Carson, 2011)[2].

As is clear from the introductory sections, the measurement and operationalisation of biodiversity are all but trivial tasks. Since there is no single 'right' indicator of biodiversity and since data constraints abound, economists who have aimed at valuing it have used various different proxies for biodiversity. In what follows, we would like to

[2] A more detailed description of the search process can be found in Appendix A.

offer a classification of the attributes valuation practitioners used as proxies[3]. The classification was specifically designed for the purposes of the review. It has been inspired by classifications proposed by Nunes et al. (2003) and Pearce (2001), but it deviates from them, first, in that it is based on a more rigorous definition of biodiversity (see section 4), and second, it was inductively adapted during the process of reviewing the valuation studies so as to enable the full attribution of all studies to the respective categories. As a result, the following attribute categories were identified:

- **Numbers**: species diversity or, more simply, species richness is often interpreted as a suitable proxy for biodiversity (Christie et al., 2007; Gaston, 1996b). Valuation studies falling into this category make use of concrete species richness numbers or use some of the relatively simpler biodiversity indices (e.g., the Shannon-Wiener index) as proxy for the level of biodiversity in the studied ecosystem.
- **Species**: often, single species or groups of species have been used to approximate biodiversity. Falling into this category are valuations of rare/threatened/endangered species, invasive species as well as changes in the abundances of (particular) species.
- **Genetics**: an important role of biodiversity is believed to be it being the carrier of option value, i.e., the value resulting from possible future utility derived from ecosystems, which is inherently linked to genetic diversity. Valuations based on the expenditures on research or bioprospecting[4] have been included in this category. Also, valuation studies focusing on preferences of consumers and farmers for different varieties of agricultural crops fall into this category.
- **Functions**: some valuation researchers have attempted to elicit the value people hold for biodiversity by referring to its role in underpinning and facilitating the functions and processes of ecosystems, which may be interpreted as reflecting the

[3] We deliberately use the word „proxies“ instead of „indicators“, as the proxies used by valuation practitioners are not always identical with the indicators ecologists use in biodiversity research (see also section 6.2).

[4] “Bioprospecting refers to the assessment of life forms for development of unique molecules, biological entities, or structures that have potential utility in the economic sphere. Examples of bioprospecting include the screening of microorganisms for the ability to metabolize oil spills, the screening of marine organisms for antifouling compounds to prevent the attachment of barnacles to ship hulls, the analysis of archael species in hot springs to discover new temperature resistant DNA polymerases, or the search for new pharmaceutical compounds from rain forest plants for the treatment of disease.” (Cox and King, 2013, p. 588)

value of biodiversity in increasing ecosystem stability and resilience (Balvanera et al., 2006; Jax, 2010; Mace et al., 2012).

- **Habitats**: a very common approach for approximating the value of biodiversity is to elicit people's values for the preservation of habitats, which is similar to the use of the biodiversity indicator 'habitat amount' by ecologists. This category also includes the ecosystem service 'biodiversity protection' (Van der Ploeg and de Groot, 2010).
- **Abstract**: in this category we subsume all valuation studies that have tried to deal with biodiversity in a more abstract way, mostly by asking people to value in contingent valuation studies scenarios of 'low', 'medium' or 'high' levels of biodiversity, without more explicit specification within the questionnaire.

An important criterion according to which the categories defined above can be divided is whether they are framed in terms of biodiversity components or in terms of its roles for human well-being. By components we mean the various 'physical' levels or aspects of biodiversity, such as species, genes etc. The roles of biodiversity include its role as insurance, as carrier of future options or as underpinning of ecosystems—in other words, we mean by 'roles' the particular ways through which biodiversity influences human well-being. As can be easily seen, *Numbers* and *Species* focus on components of biodiversity; *Genetics* and *Functions* are rather framed in terms of roles. Meanwhile, the two remaining categories *Habitats* and *Abstract* cannot be easily attributed, as they seem too imprecise to fit the distinction between roles and components in a meaningful and sensible way.

Two qualifications should be made regarding the studies included in the categories *Genetics* and *Species*. Within the *Genetics* category, studies based on the (implicit) valuations expressed in bioprospecting contracts are only included if they explicitly value genetic diversity. No attention is paid to the contracts themselves. Meanwhile, Nunes and van den Bergh (2001) included a list with a couple of such contracts in their overview of different biodiversity valuation approaches. For a thorough study of bioprospecting contracts, see ten Kate and Laird (2000). In the *Species* category, only those studies have been included whose authors specifically mention that they use rare/threatened/endangered species as proxy for biodiversity (e.g., Jacobsen et al., 2012)[5]. Meanwhile, there are many valuation studies in which these species were chosen as valuation objects for other reasons, particularly because they are often well-known, iconic species, for which values can be elicited relatively easily. Such studies have been omitted from the review.

4 Criteria for the evaluation of biodiversity proxies

Before presenting criteria that we use to evaluate biodiversity proxies found in the studies reviewed here, we would like to briefly outline our understanding of the term 'biodiversity'. A simple yet precise definition of biodiversity is that it is the multiplicity of kinds within biotic or biota-encompassing categories (Maier, 2012), including species, habitats, functional groups, genotypes etc. Biodiversity is *not* a synonym for 'nature'. It stresses the diversity of biological things without being concerned with their identity. Therefore, it cannot be said, in our opinion, that biodiversity provides ecosystem services, as it is only a characteristic of an ecosystem, the latter being the actual 'service provider'. Accordingly, biodiversity is likely to have a rather indirect value in that it is linked to some instrumentally valuable properties of an ecosystem (we call these properties the roles biodiversity plays for human well-being). For instance, in an empirical study including interviews and discussions with laypeople, Bakhtiari et al. (2014) found that such properties might be resilience and insurance value, aesthetics or option value.

As one important aim of our review is to evaluate the biodiversity proxies used in the valuation studies covered by it, it is important to provide criteria for this evaluation. We would like to propose the following three criteria:

1. A biodiversity proxy should not reduce biodiversity to one single aspect. It is a complex and multi-facetted entity, thus it is difficult to identify proxies that cover the full extent of biodiversity. For example, a small sub-category of species cannot properly capture biodiversity and its value on its own. Indeed, it might well be impossible to construct a proxy that captures all aspects of biodiversity. Nonetheless, a proper proxy should cover as many aspects and dimensions of biodiversity as possible, given data, resource and other

[5] The same criterion was used with regard to the *Habitat* proxy, of course.

constraints. A single component will not do the job: “no single component, whether genes, species, or ecosystems, is consistently a good indicator of overall biodiversity, as the components can vary independently” (MEA, 2005, p. 1).

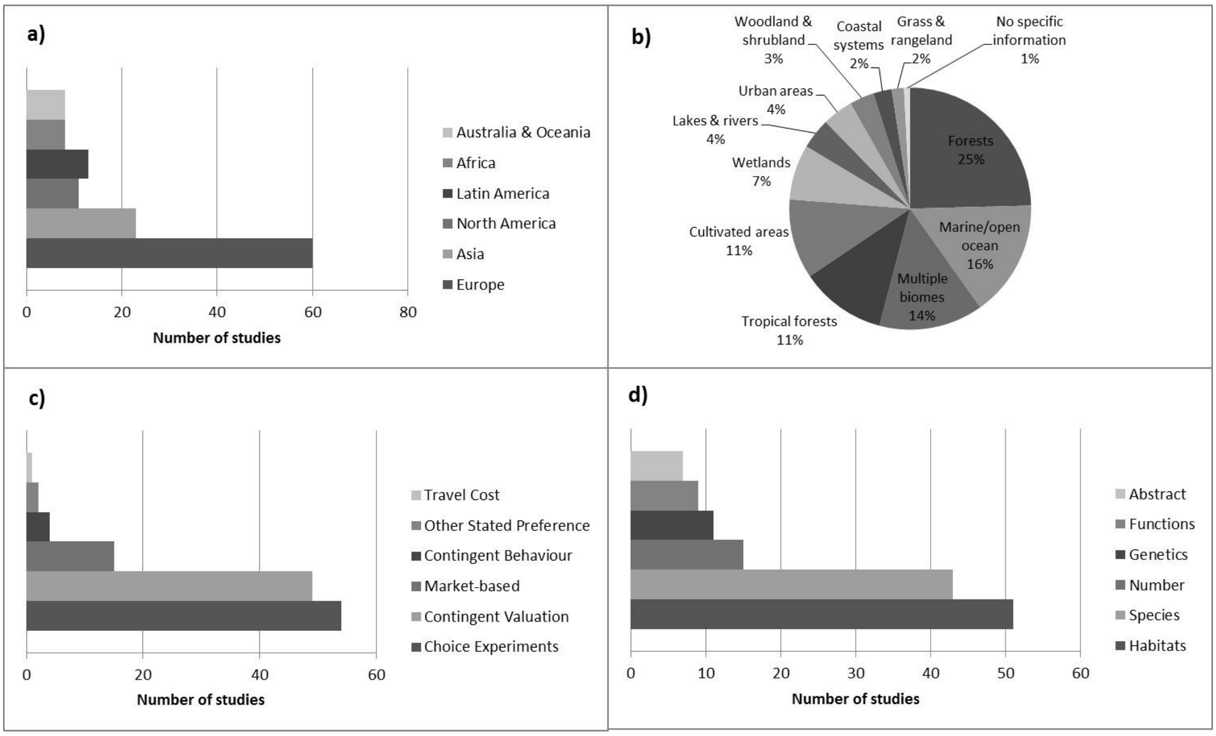
2. A biodiversity proxy should not cover more than biodiversity. As we are concerned with the economic value of the diversity of biological resources, the identity of the latter and other valuable aspects/components of natural systems are less relevant, e.g., wilderness, ecosystem services or abiotic components of ecosystems. It is crucial that biodiversity not be taken to be a synonym for ‘nature’ or ‘ecosystem’, as it is a distinct concept and only has analytic value if its distinctness is kept in mind. Good biodiversity proxies should be as precise as possible, being neither too narrow nor too encompassing.
3. The connection between the chosen biodiversity proxy and the contribution of biodiversity to human well-being should be clear. This is particularly relevant in stated preference studies, where willingness to pay (WTP) or willingness to accept compensation (WTA) for changes in biodiversity is directly elicited from members of the society. It is not enough for respondents to be aware of what biodiversity generally means for human well-being (e.g., as underpinning the stability of ecosystem services provision)—it should also be made clear to them what the specific *change* in biodiversity which is the basis of the WTP/WTA elicitation means in terms of their well-being. This calls for explicitly incorporating the change’s effects on human well-being into WTP/WTA questions. Where possible, the analysed changes should also be quantified. However, it some cases it might not possible to quantify a change in biodiversity without making it incomprehensible to respondents. A mere statement that, e.g., the number of species has changed from X to Y is unlikely to be relevant for a respondent’s assessment of her well-being. Also in studies not based on stated preference elicitation the link between biodiversity proxy and human well-being should be comprehensible as well.

We ignore for the moment the more practical criterion of data availability, although, of course, the data requirements of some biodiversity proxies are relatively more easily satisfied.

5 Review of existing biodiversity valuation studies—basic results

123 distinct studies have been found that provide economic value estimates for biodiversity[6]. Most important statistics have been summarised in Figure 1.

Figure 1 Basic results of the literature review on economic valuation of biodiversity



As can be seen in panel a), 60 studies were conducted in Europe and 23 in Asia, the other continents being represented much less frequently. Even though it is widely recognised that most biodiversity hotspots are located in the tropics, particularly in South America, equatorial Africa and South-East Asia (Myers et al., 2000), only a few economic valuation studies of biodiversity were conducted in these extremely biodiverse ideas. This finding is in accordance with a more general pattern identified by Christie et al. (2012), who found out that most valuation studies are being conducted in developed countries, whereas ecologically more valuable areas in the developing world

[6] A full list of the studies included in this review is provided in Appendix B.

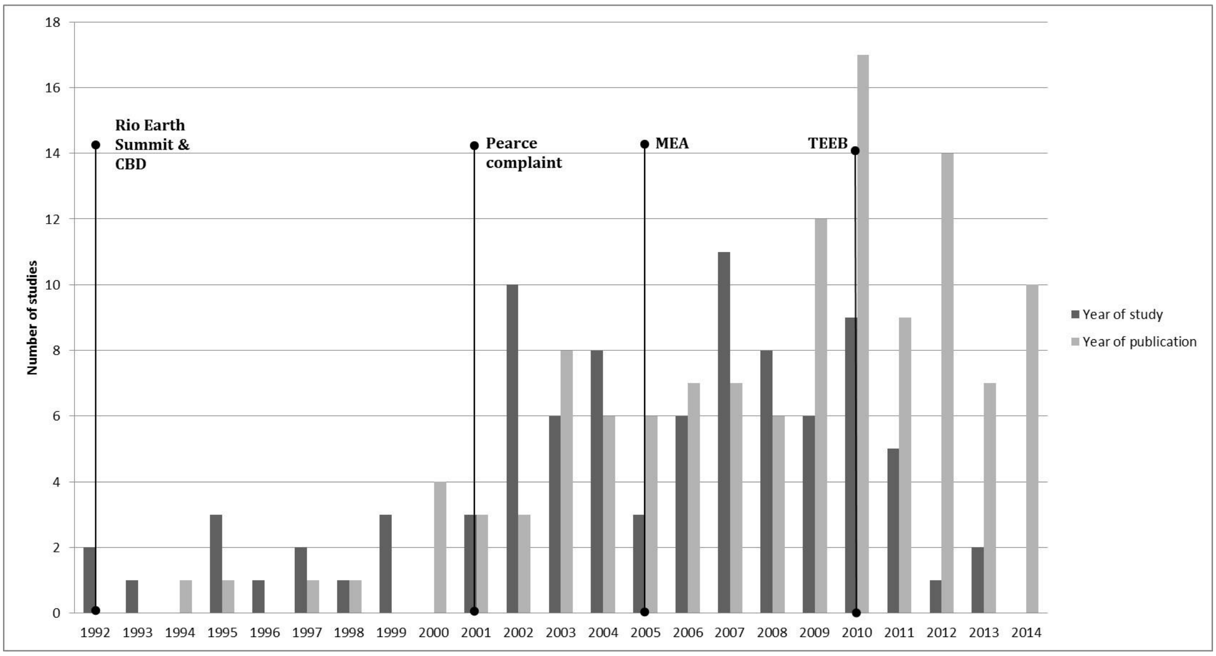
remain clearly understudied (see also Seppelt et al., 2011). This might reflect both the lack of data and skills among practitioners in developing countries and problems related to usage of monetary value categories in these regions (Norgaard, 2010).

Panel b) shows the distribution of the studies with regard to biomes covered[7]. 44 studies investigated the value of biodiversity in forest ecosystems (14 of which were tropical forests), in 19 cases the study area was marine. 17 studies covered more than one biome, in 13 cultivated areas were studied. The other biome categories are less frequent, wetlands (9 studies) being the only remaining one with more than 5 occurrences.

Before we come to panels c) and d) of Figure 1, we would like to mention the temporal distribution of the studies included in our review (see Figure 2). The two oldest studies were conducted in 1992 (Garrod and Willis, 1994; Veisten et al., 2004). After a rather slow start during the 1990's, when only a few attempts to identify the economic value of biodiversity took place, after 2000 the number of studies conducted each year more than doubled. This rise in the wake of the new millennium coincides with the publication of David Pearce's complaint about the lack of studies valuing diversity and not biological resources (Pearce, 2001). In many papers no information about the year the studies had been conducted could be found. However, when publication years are considered, the rising trend remains largely the same.

Figure 2 Temporal development of economic valuations of biodiversity

[7] The classification of biomes follows the respective TEEB classification (de Groot et al., 2010).



Let us now return to Figure 1. Panel c) reveals that a number of different valuation methods is used to value biodiversity. Stated preferences methods, notably contingent valuation (CV) and choice experiments (CE)[8] are the most common means to elicit the economic value of biodiversity with overall 103 out of 125 applications (two studies used more than one method). The other two stated preference methods (SPM) applied were contingent ranking and the Pebble Distribution Method (Anthony and Bellinger, 2007). Of those stated preference studies, four made use of deliberative approaches to economic valuation. Travel cost (TC) and contingent behaviour (CB) were employed in only 5 studies. The remaining 15 studies applied various market-based (MB) valuation methods. Panel d) summarises the most important insight from our review, viz., the use of various biodiversity proxies. The most common proxies are *Habitats* and *Species*, which were used 51 and 43 times, respectively. The other proxy categories are much less frequent: *Numbers* was used in 15 studies, *Genetics* in 11, *Functions* in 9 and *Abstract* in 7. Ten studies used multiple proxies (see also Section 6.3).

The last two statistics can be combined so as to see whether the application of particular methods depends on the proxies chosen. Table 2 maps these two aspects.

[8] Our usage of the terms reflects the common usage by practitioners (including the studies reviewed here), instead of the more consistent nomenclature proposed by Carson and Louviere (2011), which does not really reflect common practice to date.

Table 2 Dependence of attributes on methods

Attributes/methods	CE	CV	SPM	CB	TC	MB	
Habitats	11 *(0.18)*	28 *(0.54)*	0	4 *(1.0)*	1 *(1.0)*	7 *(0.47)*	51 *(0.38)*
Species	30 *(0.48)*	12 *(0.23)*	0	0	0	1 *(0.07)*	43 *(0.32)*
Numbers	10 *(0.16)*	3 *(0.06)*	1 *(0.5)*	0	0	1 *(0.07)*	15 *(0.11)*
Abstract	3 *(0.05)*	3 *(0.06)*	1 *(0.5)*	0	0	0	7 *(0.05)*
Genetics	4 *(0.06)*	5 *(0.10)*	0	0	0	2 *(0.13)*	11 *(0.08)*
Functions	4 *(0.06)*	1 *(0.02)*	0	0	0	4 *(0.27)*	9 *(0.07)*
	62	52	2	4	1	15	136

Explanation: Each cell contains the absolute number of studies using the respective combination of method and attribute. Italic numbers in brackets inform about the proportion of studies that used the specific attribute-method combination compared to the number of studies using the respective method. The bottom row and the last column indicate sums. Abbreviations: CE = Choice Experiment, CV = Contingent Valuation, SPM = other Stated Preference Methods, CB = Contingent Behaviour, TC = Travel Cost, MB = Market-Based Methods

Travel cost, contingent behaviour and 'other stated preferences' (SPM) can be ignored here because there are only very few studies using these methods. When the other three method classes are compared, two patterns are visible: first, studies that used market-based methods made use of the attributes belonging to the *Functions* category relatively often. Second, there is a difference between choice experiments and contingent valuation in that the former are more often used in combination with *Species*, the latter with *Habitats*. A possible explanation might be that *Species* can be interpreted as an attribute more 'naturally' than *Habitats*[9]. However, many choice experiment studies still did use an attribute belonging to the *Habitats* category.

6 Discussion and evaluation

[9] We are thankful to an anonymous reviewer for pointing out to us this explanation.

We would like to start the discussion by commenting on the application of valuation methods in biodiversity valuation studies. Afterwards, in section 6.2, we will evaluate the biodiversity proxies found in our review, based on the criteria developed in section 4. In section 6.3, multi-attribute studies will be presented and their strengths and shortcomings discussed.

6.1 Methods used to value biodiversity

As shown in section 5, more than 80 per cent of the reviewed studies applied either contingent valuation (CV) or choice experiments (CE). The frequency of stated preferences techniques strengthens the position, expressed for example by Meinard and Grill (2011), that this methods class offers an especially adequate means to meaningfully value the abstract good 'biodiversity'. Other methods do not have the potential to capture non-use (Pascual et al., 2010) and indirect values, which are crucial value components of biodiversity. Furthermore, four studies in our review made use of deliberative approaches to economic valuation, which combine the deliberative aspects of citizens' juries with the elicitation of individual preferences through CV or CE and better enable respondents to express their preferences for complex and unfamiliar public goods and services (Gregory, 2000; Lienhoop and MacMillan, 2007; MacMillan et al., 2002; Spash, 2007). Szabó et al. (2011) showed in the context of biodiversity valuation that deliberative approaches significantly reduce the incidence of protest bids. Both Wätzold et al. (2008) and Christie et al. (2006) applied deliberative methods in hope for learning effects and to overcome issues of unfamiliarity and complexity of the valued goods. This was also the goal of Anthony and Bellinger (2007) in a developing country context. Deliberative monetary valuation might be seen as offering a particularly well instrument for the elicitation of individual preferences for the complex good biodiversity. However, it is important to note that deliberative monetary valuation is sometimes viewed as being at odds with certain tenets of neoclassical economic theory, on which conventional economic valuation methods are based.

6.2 Evaluation of biodiversity proxies

In general, it should be emphasised that biodiversity indicators, as they are defined in ecology, are sometimes used as proxies in valuation studies, but often the proxies are not identical with indicators. This is especially the case in stated preference studies, where a biodiversity proxy fulfils a different role than a biodiversity indicator normally does. Rather than just indicating the state of or changes to biodiversity in an ecosystem, a proxy used in a questionnaire-based study is meant to symbolise biodiversity in a way that makes clear its link and contribution to human well-being.

Habitats. This proxy covers many more aspects than just the diversity of an ecosystem's components and hence it is impossible to separate out the biodiversity aspect. Furthermore, habitats include many abiotic components, whereas biodiversity is by its very definition restricted to the biotic dimension of ecosystems. Some studies have included 'biodiversity protection' as an ecosystem service, possibly following the idea behind the new service category of 'habitat services' introduced in the TEEB framework (de Groot et al., 2010). While it was shown that biomes are a relatively good predictor of species richness (Gerstner et al., 2014), the identification of biodiversity changes with changes in the extent of habitat protection appears unwarranted, at least as a generalisation[10]. Having said that, we would like to add that to determine the value of an ecosystem, it might be more sensible to value it as a whole, rather than to value single ecosystem services separately, possibly by use of different valuation methods, and to subsequently aggregate their values additively[11]. As a proxy for biodiversity in valuation studies, however, habitat protection is not sufficient and too imprecise.

Species. The use of rare/threatened/endangered or invasive species as biodiversity proxy covers only one single component of biodiversity. While it may be argued that in some cases keystone species are a good indicator of biodiversity (Haines-Young and Potschin, 2010), it is in the most cases far from trivial to identify them. The species chosen in the studies reviewed here were mostly species too marginal in an ecosystem to have a meaningful influence on its biodiversity levels. The reason why they are chosen is mostly the fact that they are endangered and/or rare, not their ecosystemic importance. In a recent exploratory study including interviews and discussions with laypeople, it was stressed that "[p]articipants were explicit that the existence of a variety

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[10] There happen to be established relationships in specific cases. See, e.g., the justification offered by Kragt et al. (2009) in the context of coral reefs.

[11] This reflects our contention that an ecosystem is "more than the sum of its parts". Furthermore, the additive aggregation of the values of single ecosystem services might lead to double counting (Fu et al., 2011).

of animals and plants was more important than any specific species.” (Bakhtiari et al., 2014, p. 31) The sole focus on single species appears unsatisfactory and likely obscures the complex relationships within an ecosystem (Mainwaring, 2001), as it suggests that the fate of single species has a general impact on overall biodiversity. Furthermore, it has been pointed out that the definition of rarity of species may itself be problematic and of limited usefulness (McIntyre, 1992). When alien species are used as a proxy, biodiversity is implicitly identified with a notion of ‘original pristinity’, which has been criticised as naïve since truly pristine ecosystems hardly exist (Ellis et al., 2013; Hobbs et al., 2013). In fact, alien species’ effects on biodiversity are very case-specific and not generally negative (Ricciardi et al., 2013; see also Warren, 2007; Gurevitch and Padilla, 2004). Also, it has been found that biodiverse ecosystems are less prone to the possibly adverse effects of alien species introductions, which is a causal chain opposite to that suggested by the invasive alien species proxy (Balvanera et al., 2006).

Numbers and Abstract. The use of numbers of species or of biodiversity indices like the Shannon-Wiener index (Polak and Shashar, 2013) can be evaluated jointly with the reference to the general, abstract concept of biodiversity, as these two approaches violate the criteria outlined in section 4 in a similar way. Both proxy categories were applied almost exclusively in stated preference studies, with the exception of one study, which used Simpson’s diversity index in a model fed by life satisfaction and market price data (Ambrey and Fleming, 2014). Stated preference methods make it necessary to make clear to respondents the links between the biodiversity proxy and human well-being. For this, the informational basis of ecological biodiversity measures or vague concepts is very limited. For example, for a layperson it may not be clear what the actual meaning of a specific number of species is. Jacobsen et al. (2008) showed that knowledge of concrete species in the ‘biodiversity mix’ increases people’s value placed on biodiversity (WTP). In their interpretation, this might be an overestimation of the actual value of biodiversity. However, another possible interpretation could be that the identified discrepancy between WTP for ‘abstract’ biodiversity and WTP for biodiversity of concrete species is due to insufficient understanding of the abstract concept by the interviewees (see also Martín-López et al., 2008). Bakhtiari et al. (2014) found that because people identify biodiversity’s functional aspects as a crucial component of its value, “using species numbers as an attribute of a CE study would not cover the true value the general public has for biodiversity” (p. 33).

Functions. This category emphasises roles rather than components of biodiversity (for definitions, see section 4). Thus, the link to human well-being is relatively clear. However, one might be tempted to argue that this approach is redundant: biodiversity positively influences the stability and resilience of ecosystems (Balvanera et al., 2006), thus also stabilising the generation and provision of ecosystem services (Mace et al., 2012). The latter have a direct influence on human well-being and are therefore the appropriate objects of valuation (Boyd and Banzhaf, 2007). Under this perspective, valuation of biodiversity and its influence on ecosystem functioning would result in double-counting (Hamilton, 2013). However, it is possible to argue that a) the double-counting issue only arises in accounting-like applications, not when the goal of valuation is to provide information about and to communicate the value of biodiversity, and b) the stabilising effect of biodiversity has a value going beyond that of the services ‘reliably’ provided by a stable ecosystem. Indeed, this perspective is very close to the notions of precautionary principle and insurance/option value (Aldred, 2013).

Genetics. Also closely related to the notion of option value is the approach behind the valuation studies falling in the *Genetics* category. Similar to *Functions*, this proxy focuses on roles rather than components of biodiversity. Two main sub-approaches can be distinguished here: one group of studies focuses on agricultural varieties and their attractiveness for either farmers or consumers (e.g., Birol et al., 2009; Dinis et al., 2011), while others base their estimates of biodiversity value on information about bioprospecting contracts and research expenditures (e.g., Erwin et al., 2010; Jobstvogt et al., 2014). Both implicitly emphasise an important role of biodiversity as ‘library’ (Goeschl and Swanson, 2007; Weitzman, 1995), which contains information that may have value in the future (see also Farnsworth et al., 2012).

According to the interpretation presented in this section, the most common approaches to the economic valuation of biodiversity do not fulfil the criteria presented in section 4. They are often too unspecific, either being too broad or too narrow to capture the essence of biodiversity. In fact, even the two approaches that appear most satisfactory, namely *Functions* and *Genetics,* are by themselves rather limited in their comprehensiveness and cannot capture the whole complexity of the notion of biodiversity on their own.

In some studies, however, the attempt was made to operationalise biodiversity by use of more than one proxy/attribute. In the following section, these studies will be discussed in some more detail, as they offer an approach that captures biodiversity in a more precise way, being neither too narrow nor too encompassing.

6.3 Multi-attribute descriptions of biodiversity

Biodiversity is a multidimensional concept; hence describing biodiversity with multiple attributes[12] seems to be a sensible approach. Our review reveals that this was done in 10 studies. Table 3 presents a list of these studies and the attributes their authors used to describe biodiversity in the respective studies.

Table 3 Multi-attribute biodiversity valuation studies

Study	Attributes	Proxy categories
Birol et al. (2009a)	• "number of different species [and] their population levels" • "number of different habitats and their size"	• Species • Habitats
Christie et al. (2006)	• "familiar species of wildlife" • "rare (unfamiliar) species of wildlife" • "habitat" • "ecosystem processes"	• Species • Species • Habitats • Functions
Czajkowski et al. (2009)	• "natural ecological processes" • "rare species of fauna and flora" • "ecosystem components"	• Functions • Species • Habitats
Eggert and Olsson (2009)	• "richness in species and richness within each species" • "important for the sea's capacity to handle environmental disturbances, but also for productivity"	• Species • Functions
Garber-Yonts et al. (2004)	• "biodiversity reserves" • "endangered species"	• Habitats • Species

[12] In what follows, "attribute" and "proxy" will be used interchangeably, as the former term is often used in economics to describe a good's (here: biodiversity) characteristics.

	• "forest age management"	• Habitats
Jobstvogt et al. (2014)	• "number of protected species" • "[potential] new medicinal products"	• Species • Genetics
Lehtonen et al. (2003)	• "number of endangered species" • "conservation areas" • "[number of] biotopes at favourable levels of conservation"	• Species • Habitats • Habitats
Liebe and Preisendörfer (2007)	• "biotopes of rare species" • "species richness" • "age structure of the forests" • "landscape diversity"	• Habitats/Species • Numbers • Habitats • Habitats
MacMillan et al. (2001)	• "restoration of native forest" • "reintroduction of the beaver/wolf"	• Habitats • Species
Rajmis et al. (2010)	• "dangers from alien species" • "resilience"	• Species • Functions

In all multi-attribute studies some version of the proxy category Species was applied, mostly involving rare or endangered species, in one case alien species (Rajmis et al., 2010)[13]. Furthermore, 7 of these 10 studies used a proxy belonging to the Habitats category in their multi-attribute description of biodiversity. Also, nearly half of all studies focusing on *Functions* (4 of 9) used a multi-attribute approach. This confirms the intuition that, while *Functions* alone might be viewed as too imprecise and thus uninformative, it still reflects an important aspect of biodiversity value. Finally, attributes belonging to the categories *Numbers* and *Genetics* were used once each.

Two interesting attributes proposed are "landscape diversity" in Liebe and Preisendörfer (2007) and "ecosystem components" in Czajkowski et al. (2009) (by which the latter mean dead wood, ponds, streams etc.). Both seem to emphasise abiotic components of ecosystems, which *ex definitione* are not part of *bio*diversity. However, at least in the latter case it might be argued that these ecosystem components can be considered potentially biodiverse 'micro-habitats'. This means, on the one hand, that the critique of the *Habitats* category applies at least partly. On the other hand, this attribute is an

[13] Indeed, contrary to the common use of the occurrence of invasive alien species as a proxy for biodiversity, Rajmis et al. seem to emphasise the role of biodiversity in protecting ecosystems against negative effects of alien species, which would actually fit the *Functions* category.

important attempt to take into account the astonishing biodiversity of insects and microbes living largely unnoticed in such micro-habitats.

While the emphasis of the roles biodiversity plays in enhancing human well-being was explicit in some of the attributes found here, most studies focused on components, Rajmis et al. (2010) being the only study that had a clear roles focus, stressing the 'functionality' of biodiversity (Bakhtiari et al., 2014). As will be discussed in the next section, this constitutes a major research gap and an opportunity to enhance the practice of economic valuation of biodiversity.

Given the predominantly indirect, non-use nature of biodiversity value, the most encompassing way to value it is by means of stated preference methods (Pascual et al., 2010; Hansjürgens et al., 2012). In a multi-attribute approach, non-use values are likely to be relevant for at least some of the proxies used. Hence it is not surprising that all 10 studies applied either choice experiments or contingent valuation. Also, as choice experiments are a method specifically designed to take into account the multitude of good characteristics (attributes) and their respective influence on utility, it is not surprising that in 8 of the multi-attribute studies this method was applied.

In general, the multi-attribute approach to economic valuation of biodiversity appears very promising because it allows to better mirror the complexity and multidimensionality of biodiversity than single-proxy approaches. At the same time, it allows to keep the underlying description of biodiversity specific without becoming too encompassing. Therefore, we consider these multi-attribute studies as representing best practice within our review. Especially the studies by Christie et al. (2006) and Czajkowski et al. (2009) offer highly innovative and conceptually appealing approaches. However, it might be worth putting more emphasis on the roles of biodiversity instead of framing it in terms of its components (with the roles being only implicitly related to them). This approach has, of course, limitations. One clear limitation is data: our understanding of biodiversity and its effects on both eco- and human systems is still very limited, and for many ecosystems data related to biodiversity are lacking (Hansjürgens et al., 2012). Furthermore, when biodiversity is valued via stated preferences methods, the main challenge is to determine the right amount of information provided to respondents that allows them to thoroughly understand the valuation object but does not lead to a cognitive overstrain (e.g., MacMillan et al., 2006). In addition, there might be a trade-off between stressing the roles biodiversity plays for human well-being, its ‘functionality’ (Bakhtiari et al., 2014), and using quantifiable attributes, as recommended, e.g., by Bateman et al. (2004)[14].

7 Conclusions and recommendations for future research

The goal of the present review of studies that economically valued biodiversity has been threefold: to give an overview about the state of the art in this area of research, including a clustering and comparison of approaches; to identify the strengths and weaknesses of the approaches found in the relevant body of applied literature, including the identification of best-practice studies; and to offer on that basis an orientation as to how biodiversity might be valued appropriately and so as to account for the complexity of the concept.

The review revealed a whole array of different approaches, but at the same time showed that some of them are particularly frequent. Most importantly, around 80 per cent of the studies applied stated preference methods. A similar share used biodiversity proxies belonging to two attribute categories, based on the notions of habitat protection and rare/endangered/alien species, respectively. Even though the complexity and multidimensionality of the biodiversity concept is well recognised, only a few studies tried to approach it in a multi-attribute way. Also, only four studies applied deliberative valuation methods. In most cases, valuation was based on components of biodiversity (particularly species), less on the roles it plays for human well-being (e.g., as insurance or carrier of option value).

Based on our review we would like to suggest the following recommendations or orientation remarks on the road towards more consistent and comprehensive valuation of biodiversity:

First, given the concept’s complexity, it appears essential to approach biodiversity on the basis of multiple attributes. Biodiversity not only encompasses a number of levels and components, ranging from genes to species to functional groups, it also plays a

[14] We are thankful to an anonymous reviewer for pointing this out to us.

number of different roles within ecosystems—and, consequentially, influences human well-being in many different ways. Reliance on single-attribute proxies is problematic because it tends to lead to one of two extremes: either the proxy is too encompassing and unspecific (e.g., habitat protection) or it is too narrow and focuses on one single aspect of biodiversity (e.g., rare species). Of course, there are obstacles and trade-offs involved in the multi-attribute approach, too. First, the inclusion of too many attributes in stated preference based valuation may overtax respondents and thus lead to less valid value estimates. In valuation of complex environmental goods there is a general trade-off between simplicity of presentation of the good and the quality of results. Here, focus group research and careful pre-testing of the questionnaire help to determine the amount of attributes that respondents are able to cope with. Second, data constraints might play a role and inhibit the inclusion or specification of particular attributes. Nonetheless, we believe that economic valuation of biodiversity should be based on the use of multiple attributes. The problems related to this approach are serious, but not insurmountable. In the end, it is a question of balance between the extremes of too little and too much specificity. There is a need for more research into the operationalisation of biodiversity for valuation purposes in a multi-attribute way.

Second, the trade-off between biodiversity's complexity and the cognitive limitations of humans (including the respondents in stated preference based valuation studies) might be eased by providing more-than-usual time and information to the respondents, e.g., through deliberative valuation methods. While still relying on the elicitation of individual preferences, these methods facilitate the formation of informed preferences for unfamiliar and complex environmental public goods such as biodiversity by giving respondents sufficient information, time to think, room for discussion and clarification. All these aspects are highly relevant when respondents have to make up their mind about how important biodiversity is to them and how much it is worth to them in monetary terms. Of course, other ways are also thinkable to ease the acquisition and accommodation of complex information by respondents in stated preference studies, e.g., through the use of web-based surveys (Lindhjem and Navrud, 2011). It is crucial, however, to keep in mind that biodiversity is an exceptionally complex and unfamiliar environmental good that might overstretch the capacity of usual stated preference methodology.

Finally, we believe that it is less useful to describe biodiversity for valuation purposes in terms of its components, be it species, genes or biodiversity indices. Rather, biodiversity's influence on human well-being, the roles it plays—as carrier of option value, as insurance, as underpinning of stable ecosystems etc.—should be at centre. This is related to the observation that people around the world are unfamiliar with the concept of biodiversity. Furthermore, being a concept and not a physical entity, biodiversity influences human well-being in a rather indirect way (or, actually, in a multiplicity of ways). The emphasis put on roles, not on components, shortens the distance cognitive processes must cover both in the process of preference formation and while translating those into monetary values. We are aware that a roles-based approach brings with it the difficulty of finding quantifiable attributes. In some cases, there might be a trade-off between quantifiability and meaningfulness for the respondents. There is a need to formulate a coherent framework for the valuation of biodiversity based on the roles it plays that would be feasible for practical application.

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Appendix A

The literature search for the review was conducted as follows:

1. The Web of Science data base was searched by use of the following terms: "economic valu*", "contingent valuation", "choice model*", "choice experiment", "conjoint analysis", "contingent behavio*r", "travel cost", "wtp", "willingness*to*pay", "pric*" and "biodiversity", "biological diversity", "rare species", "endangered species", "threatened species", "alien species" (title, key words, abstracts). Only peer-reviewed articles were considered.
2. The resulting output was investigated more thoroughly: titles and abstracts were read (in ambivalent cases also the text body) so as to sort out articles not being valuation studies (e.g., conceptual papers).
3. The remaining articles were read so as to find out whether biodiversity was actually among the valuation objects. Where this was not the case, the respective publications were sorted out.
4. The TEEB Valuation Database was searched for articles which valued the ecosystem service "biodiversity protection".
5. Carson's Contingent Valuation Bibliography was searched for "biodiversity" and "biological diversity" as a check whether any relevant articles had been missed.
6. For the most recent articles (March-October 2014), Google Scholar was searched using the combination of "valuation" and "biodiversity" in a full-text search.
7. If a valuation study was covered in more than one article, only the earliest peer-reviewed publication was included.

References

Aldred, J., 2013. Justifying precautionary policies: Incommensurability and uncertainty. Ecol. Econ. 96, 132–140. doi:10.1016/j.ecolecon.2013.10.006

Ambrey, C.L., Fleming, C.M., 2014. Valuing Ecosystem Diversity in South East Queensland: A Life Satisfaction Approach. Soc. Indic. Res. 115, 45–65. doi:10.1007/s11205-012-0208-4

Anthony, B.P., Bellinger, E.G., 2007. Importance value of landscapes, flora and fauna to Tsonga communities in the rural areas of Limpopo province, South Africa. South Afr. J. Sci. 103, 148–154.

Atkinson, G., Bateman, I., Mourato, S., 2012. Recent advances in the valuation of ecosystem services and biodiversity. Oxf. Rev. Econ. Policy 28, 22–47. doi:10.1093/oxrep/grs007

Bakhtiari, F., Jacobsen, J.B., Strange, N., Helles, F., 2014. Revealing lay people's perceptions of forest biodiversity value components and their application in valuation method. Glob. Ecol. Conserv. 1, 27–42. doi:10.1016/j.gecco.2014.07.003

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.-S., Nakashizuka, T., Raffaelli, D., Schmid, B., 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecol. Lett. 9, 1146–1156. doi:10.1111/j.1461-0248.2006.00963.x

Bateman, I., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroğlu, E., Pearce, D.W., Sugden, R., Swanson, J., 2004. Economic Valuation With Stated Preference Techniques: A Manual. Edward Elgar, Cheltenham.

Baumgärtner, S., 2007. Why the measurement of species diversity requires prior value judgements, in: Kontoleon, A., Pascual, U., Swanson, T.M. (Eds.), Biodiversity Economics. Cambridge University Press, Cambridge; New York, pp. 293–310.

Birol, E., Villalba, E.R., Smale, M., 2009. Farmer preferences for milpa diversity and genetically modified maize in Mexico: a latent class approach. Environ. Dev. Econ. 14, 521–540. doi:10.1017/S1355770X08004944

Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63, 616–626. doi:10.1016/j.ecolecon.2007.01.002

Butchart, S.H.M., Walpole, M., Collen, B., Strien, A. van, Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C., Watson, R., 2010. Global Biodiversity: Indicators of Recent Declines. Science 328, 1164–1168. doi:10.1126/science.1187512

Carson, R.T., 2011. Contingent Valuation: A Comprehensive Bibliography and History. Edward Elgar, Cheltenham; Northampton.

Carson, R.T., Louviere, J.J., 2011. A Common Nomenclature for Stated Preference Elicitation Approaches. Environ. Resour. Econ. 49, 539–559. doi:10.1007/s10640-010-9450-x

CBD, 1992. Convention on Biological Diversity. United Nations.

CBD, 2011. Report of the Ad hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011-2020. UNEP/CBD, Montreal.

Christie, M., Fazey, I., Cooper, R., Hyde, T., Kenter, J.O., 2012. An evaluation of monetary and non-monetary techniques for assessing the importance of biodiversity and ecosystem services to people in countries with developing economies. Ecol. Econ. 83, 67–78. doi:10.1016/j.ecolecon.2012.08.012

Christie, M., Hanley, N., Warren, J., Hyde, T., Murphy, K., Wright, R., 2007. Valuing ecological and anthropocentric concepts of biodiversity: a choice experiments application, in: Kontoleon, A., Pascual, U., Swanson, T.M. (Eds.), Biodiversity Economics. Cambridge University Press, Cambridge; New York, pp. 343–368.

Christie, M., Hanley, N., Warren, J., Murphy, K., Wright, R., Hyde, T., 2006. Valuing the diversity of biodiversity. Ecol. Econ. 58, 304–317. doi:10.1016/j.ecolecon.2005.07.034

Christie, M., Warren, J., Hanley, N., Murphy, K., Wright, R., 2004. Developing measures for valuing changes in biodiversity: final report (Report). DEFRA, London.

Cox, P.A., King, S., 2013. Bioprospecting, in: Levin, S.A. (Ed.), Encyclopedia of Biodiversity. Elsevier, Amsterdam, pp. 588–599.

Czajkowski, M., Buszko-Briggs, M., Hanley, N., 2009. Valuing changes in forest biodiversity. Ecol. Econ. 68, 2910–2917. doi:10.1016/j.ecolecon.2009.06.016

Daily, G.C. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

DEFRA, 2007. Report, questionnaire and data tables following Survey of Public Attitudes and Behaviours toward the Environment: 2007. defra, London.

De Groot, R.S., Fisher, B., Christie, M., 2010. Integrating the Ecological and Economic Dimensions in Biodiversity and Ecosystem Service Valuation, in: Kumar, P. (Ed.), The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Routledge, London; New York, pp. 9–40.

De Groot, R.S., Wilson, M.A., Boumans, R.M.., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 41, 393–408. doi:10.1016/S0921-8009(02)00089-7

DeLong, D.C., 1996. Defining Biodiversity. Wildl. Soc. Bull. 24, 738–749. doi:10.2307/3783168

Dinis, I., Simoes, O., Moreira, J., 2011. Using sensory experiments to determine consumers' willingness to pay for traditional apple varieties. Span. J. Agric. Res. 9. doi:10.5424/sjar/20110902-133-10

Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Goldewijk, K.K., Verburg, P.H., 2013. Used planet: A global history. Proc. Natl. Acad. Sci. 201217241. doi:10.1073/pnas.1217241110

Elmqvist, T., Maltby, E., Barker, T., Mortimer, M., Perrings, C., 2010. Biodiversity, Ecosystems and Ecosystem Services, in: Kumar, P. (Ed.), The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Routledge, London; New York, pp. 41–111.

Erwin, P.M., López-Legentil, S., Schuhmann, P.W., 2010. The pharmaceutical value of marine biodiversity for anti-cancer drug discovery. Ecol. Econ. 70, 445–451. doi:10.1016/j.ecolecon.2010.09.030

Farnsworth, K.D., Lyashevska, O., Fung, T., 2012. Functional complexity: The source of value in biodiversity. Ecol. Complex. 11, 46–52. doi:10.1016/j.ecocom.2012.02.001

Figge, F., 2004. Bio-folio: applying portfolio theory to biodiversity. Biodivers. Conserv. 13, 827–849. doi:10.1023/B:BIOC.0000011729.93889.34

Fu, B.-J., Su, C.-H., Wei, Y.-P., Willett, I.R., Lü, Y.-H., Liu, G.-H., 2011. Double counting in ecosystem services valuation: causes and countermeasures. Ecol. Res. 26, 1–14. doi:10.1007/s11284-010-0766-3

Garrod, G.D., Willis, K.G., 1994. Valuing biodiversity and nature conservation at a local level. Biodivers. Conserv. 3, 555–565. doi:10.1007/BF00115161

Gaston, K.J., 1996a. What is biodiversity?, in: Gaston, K.J. (Ed.), Biodiversity: A Biology of Numbers and Difference. Blackwell Science, Cambridge, MA, pp. 1–9.

Gaston, K.J., 1996b. Species richness: measure and measurement, in: Gaston, K.J. (Ed.), Biodiversity: A Biology of Numbers and Difference. Blackwell Science, Cambridge, MA, pp. 77–113.

Gerstner, K., Dormann, C.F., Václavík, T., Kreft, H., Seppelt, R., 2014. Accounting for geographical variation in species–area relationships improves the prediction of plant species richness at the global scale. J. Biogeogr. 41, 261–273. doi:10.1111/jbi.12213

Goeschl, T., Swanson, T.M., 2007. Designing the legacy library of genetic resources: approaches, methods and results, in: Kontoleon, A., Pascual, U., Swanson, T.M. (Eds.), Biodiversity Economics. Cambridge University Press, Cambridge; New York.

Gregory, R., 2000. Using Stakeholder Values to Make Smarter Environmental Decisions. Environ. Sci. Policy Sustain. Dev. 42, 34–44. doi:10.1080/00139150009604888

Gurevitch, J., Padilla, D.K., 2004. Are invasive species a major cause of extinctions? Trends Ecol. Evol. 19, 470–474. doi:10.1016/j.tree.2004.07.005

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being, in: Raffaelli, D.G., Frid, C. (Eds.), Ecosystem Ecology: A New Synthesis, Ecological Reviews. Cambridge University Press, Cambridge; New York, pp. 110–139.

Hamilton, K., 2013. Biodiversity and National Accounting (No. WPS 6441). World Bank, Washington, D.C.

Hansjürgens, B., Lienhoop, N., Herkle, S., 2012. Grenzen und Reichweite der ökonomischen Bewertung von Biodiversität (Limits and scope of economic valuation of biodiversity) (Expert opinion report). Office of Technology Assessment at the German Bundestag, Berlin.

Heal, G.M., 2000. Nature and the Marketplace: Capturing the Value of Ecosystem Services. Island Press, Washington, D.C.

Hobbs, R.J., Higgs, E.S., Hall, C.M. (Eds.), 2013. Novel Ecosystems: Intervening in the New Ecological World Order. Wiley-Blackwell, Chichester, West Sussex ; Hoboken, NJ.

Jacobsen, J.B., Boiesen, J.H., Thorsen, B.J., Strange, N., 2008. What's in a name? The use of quantitative measures versus "Iconised" species when valuing biodiversity. Environ. Resour. Econ. 39, 247–263. doi:10.1007/s10640-007-9107-6

Jacobsen, J.B., Lundhede, T.H., Thorsen, B.J., 2012. Valuation of wildlife populations above survival. Biodivers. Conserv. 21, 543–563. doi:10.1007/s10531-011-0200-3

Jax, K., 2010. Ecosystem Functioning, Ecology, biodiversity and conservation. Cambridge University Press, Cambridge; New York.

Jobstvogt, N., Hanley, N., Hynes, S., Kenter, J., Witte, U., 2014. Twenty thousand sterling under the sea: Estimating the value of protecting deep-sea biodiversity. Ecol. Econ. 97, 10–19. doi:10.1016/j.ecolecon.2013.10.019

Kahn, J.R., O'Neill, R., Stewart, S., 2001. Stated Preference Approaches to the Measurement of the Value of Biodiversity, in: OECD (Ed.), Valuation of Biodiversity Benefits: Selected Studies. OECD, Paris, pp. 91–119.

Koricheva, J., Siipi, H., 2004. The Phenomenon of Biodiversity, in: Oksanen, M., Pietarinen, J. (Eds.), Philosophy and Biodiversity. Cambridge University Press, Cambridge, pp. 27–53.

Kragt, M.E., Roebeling, P.C., Ruijs, A., 2009. Effects of Great Barrier Reef degradation on recreational reef-trip demand: a contingent behaviour approach. Aust. J. Agric. Resour. Econ. 53, 213–229. doi:10.1111/j.1467-8489.2007.00444.x

Kumar, P. (Ed.), 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Routledge, London; New York.

Liebe, U., Preisendörfer, P., 2007. Zahlungsbereitschaft für kollektive Umweltgüter. Theoretische Grundlagen und empirische Analysen am Fallbeispiel der Wertschätzung biologischer Vielfalt im Wald. Z. Für Soziol. 36, 326–345.

Lienhoop, N., MacMillan, D.C., 2007. Valuing wilderness in Iceland: Estimation of WTA and WTP using the market stall approach to contingent valuation. Land Use Policy 24, 289–295. doi:10.1016/j.landusepol.2005.07.001

Lindhjem, H., Navrud, S., 2011. Are Internet surveys an alternative to face-to-face interviews in contingent valuation? Ecol. Econ. 70, 1628–1637. doi:10.1016/j.ecolecon.2011.04.002

Mace, G.M., 2014. Biodiversity: Its Meanings, Roles, and Status, in: Helm, D., Hepburn, C. (Eds.), Nature in the Balance: The Economics of Biodiversity. Oxford University Press, New York, pp. 35–56.

Mace, G.M., Norris, K., Fitter, A.H., 2012. Biodiversity and ecosystem services: a multilayered relationship. Trends Ecol. Evol. 27, 19–26. doi:10.1016/j.tree.2011.08.006

MacMillan, D.C., Hanley, N., Lienhoop, N., 2006. Contingent valuation: Environmental polling or preference engine? Ecol. Econ. 60, 299–307. doi:10.1016/j.ecolecon.2005.11.031

MacMillan, D.C., Philip, L., Hanley, N., Alvarez-Farizo, B., 2002. Valuing the non-market benefits of wild goose conservation: a comparison of interview and group based approaches. Ecol. Econ. 43, 49–59. doi:10.1016/S0921-8009(02)00182-9

Maier, D.S., 2012. What's So Good About Biodiversity? A Call for Better Reasoning About Nature's Value, The International Library of Environmental, Agricultural and Food Ethics. Springer, Dordrecht; New York.

Mainwaring, L., 2001. Biodiversity, Biocomplexity, and the Economics of Genetic Dissimilarity. Land Econ. 77, 79. doi:10.2307/3146982

Martín-López, B., Montes, C., Benayas, J., 2008. Economic Valuation of Biodiversity Conservation: the Meaning of Numbers. Conserv. Biol. 22, 624–635. doi:http://dx.doi.org/10.1111/j.1523-1739.2008.00921.x

McIntyre, S., 1992. Risks associated with the setting of conservation priorities from rare plant species lists. Biol. Conserv. 60, 31–37. doi:10.1016/0006-3207(92)90796-P

MEA, 2005. Ecosystems and Human Well-Being: Biodiversity Synthesis. World Resources Institute, Washington, D.C.

Meinard, Y., Grill, P., 2011. The economic valuation of biodiversity as an abstract good. Ecol. Econ. 70, 1707–1714. doi:10.1016/j.ecolecon.2011.05.003

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858. doi:10.1038/35002501

Nahlik, A.M., Kentula, M.E., Fennessy, M.S., Landers, D.H., 2012. Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. Ecol. Econ. 77, 27–35. doi:10.1016/j.ecolecon.2012.01.001

Norgaard, R.B., 2010. Ecosystem services: From eye-opening metaphor to complexity blinder. Ecol. Econ. 69, 1219–1227. doi:10.1016/j.ecolecon.2009.11.009

Nunes, P.A.L.D., van den Bergh, J.C.J.M., 2001. Economic valuation of biodiversity: sense or nonsense? Ecol. Econ. 39, 203–222. doi:10.1016/S0921-8009(01)00233-6

Nunes, P.A.L.D., van den Bergh, J.C.J.M., Nijkamp, P., 2003. The Ecological Economics of Biodiversity: Methods and Applications. Edward Elgar, Cheltenham; Northampton.

Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., Verma, M., 2010. The Economics of Valuing Ecosystem Services and Biodiversity, in: Kumar, P. (Ed.), The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Routledge, London; New York, pp. 183–256.

Pearce, D.W., 2001. Valuing Biological Diversity: Issues and Overview, in: OECD (Ed.), Valuation of Biodiversity Benefits: Selected Studies. OECD, Paris, pp. 27–44.

Pearce, D.W., Moran, D., 1994. The Economic Value of Biodiversity. Earthscan, London.

Pereira, H.M., Ferrier, S., Walters, M., Geller, G.N., Jongman, R.H.G., Scholes, R.J., Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C., Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Karp, D.S., McGeoch, M.A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B., Sayre, R., Scharlemann, J.P.W., Stuart, S.N., Turak, E., Walpole, M., Wegmann, M., 2013. Essential Biodiversity Variables. Science 339, 277–278. doi:10.1126/science.1229931

Polak, O., Shashar, N., 2013. Economic value of biological attributes of artificial coral reefs. ICES J. Mar. Sci. 70, 904–912. doi:10.1093/icesjms/fst014

Rajmis, S., Barkmann, J., Marggraf, R., 2010. Pythias Rache: zum ökonomischen Wert ökologischer Risikovorsorge. GAIA 19, 114–121.

Ricciardi, A., Hoopes, M.F., Marchetti, M.P., Lockwood, J.L., 2013. Progress toward understanding the ecological impacts of nonnative species. Ecol. Monogr. 83, 263–282. doi:10.1890/13-0183.1

Seppelt, R., Dormann, C.F., Eppink, F.V., Lautenbach, S., Schmidt, S., 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. J. Appl. Ecol. 48, 630–636. doi:10.1111/j.1365-2664.2010.01952.x

Solow, A., Polasky, S., Broadus, J., 1993. On the Measurement of Biological Diversity. J. Environ. Econ. Manag. 24, 60–68. doi:10.1006/jeem.1993.1004

Spash, C.L., 2007. Deliberative monetary valuation (DMV): Issues in combining economic and political processes to value environmental change. Ecol. Econ. 63, 690–699. doi:10.1016/j.ecolecon.2007.02.014

Swanson, T.M. (Ed.), 1998. The Economics and Ecology of Biodiversity Decline: The Forces Driving Global Change. Cambridge University Press, Cambridge.

Swingland, I.R., 2013. Definition of Biodiversity, in: Levin, S.A. (Ed.), Encyclopedia of Biodiversity. Elsevier, Amsterdam, pp. 399–410.

Szabó, Z., 2011. Reducing protest responses by deliberative monetary valuation: Improving the validity of biodiversity valuation. Ecol. Econ. 72, 37–44. doi:10.1016/j.ecolecon.2011.09.025

Takacs, D., 1996. The Idea of Biodiversity: Philosophies of Paradise. Johns Hopkins University Press, Baltimore.

Ten Kate, K., Laird, S.A., 2000. The commercial use of biodiversity: access to genetic resources and benefit-sharing. Earthscan, London.

Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V., Georgiou, S., 2003. Valuing nature: lessons learned and future research directions. Ecol. Econ. 46, 493–510. doi:10.1016/S0921-8009(03)00189-7

UEBT, 2013. Biodiversity Barometer 2013.

Van der Ploeg, S., de Groot, R.S., 2010. The TEEB Valuation Database - a searchable database of 1310 estimates of monetary values of ecosystem services.

Veisten, K., Fredrik Hoen, H., Navrud, S., Strand, J., 2004. Scope insensitivity in contingent valuation of complex environmental amenities. J. Environ. Manage. 73, 317–331. doi:10.1016/j.jenvman.2004.07.008

Warren, C.R., 2007. Perspectives on the `alien' versus `native' species debate: a critique of concepts, language and practice. Prog. Hum. Geogr. 31, 427–446. doi:10.1177/0309132507079499

Wätzold, F., Lienhoop, N., Drechsler, M., Settele, J., 2008. Estimating optimal conservation in the context of agri-environmental schemes. Ecol. Econ. 68, 295–305. doi:10.1016/j.ecolecon.2008.03.007

Weitzman, M.L., 1992. On Diversity. Q. J. Econ. 107, 363–405. doi:10.2307/2118476

Weitzman, M.L., 1995. Diversity functions, in: Perrings, C., Folke, C., Mäler, K.-G., Holling, C.S., Jansson, B.-O. (Eds.), Biodiversity Loss: Economic and Ecological Issues. Cambridge University Press, Cambridge, pp. 21–43.

Weitzman, M.L., 1998. The Noah's Ark Problem. Econometrica 66, 1279. doi:10.2307/2999617

Weitzman, M.L., 2000. Economic Profitability Versus Ecological Entropy. Q. J. Econ. 115, 237–263. doi:10.1162/003355300554728

Appendix B

Table B.1 List of all valuation studies included in the review

Authors	**(Earliest peer-reviewed) publication**	**Year**	**Attributes**					
			Abstract	*Number*	*Genetics*	*Species*	*Functions*	*Habitats*
Multi-attribute studies								
Birol et al	Optimal management of wetlands: Quantifying trade-offs between flood risks, recreation, and biodiversity conservation, Water Resources Research 45(11)	2009				x		x
Christie et al	Valuing the diversity of biodiversity, Ecological Economics 58(2)	2006				x	x	x
Czajkowski et al	Valuing changes in forest biodiversity, Ecological Economics 68(12)	2009				x	x	x
Eggert and Olsson	Valuing multi-attribute marine water quality, Marine Policy 33(2)	2009				x	x	
Garber-Yonts et al	Public Values for Biodiversity Conservation Policies in the Oregon Coast Range, Forest Science 50(5)	2004				x		x
Jobstvogt et al	Twenty thousand sterling under the sea: Estimating the value of protecting deep-sea biodiversity, Ecological Economics 97	2014			x	x		
Lehtonen et al	Non-market benefits of forest conservation in southern Finland, Environmental Science & Policy 6(3)	2003				x		x
Liebe and Preisendörfer	Zahlungsbereitschaft für kollektive Umweltgüter. Theoretische Grundlagen und empirische Analysen am Fallbeispiel der Wertschätzung biologischer Vielfalt im Wald, Zeitschrift für Soziologie 36(5)	2007		x		x		x
MacMillan et al	Modelling the Non-market Environmental Costs and Benefits of Biodiversity Projects Using Contingent Valuation Data, Environmental and Resource Economics 18(4)	2001				x		x

Rajmis et al	Pythias Rache: zum ökonomischen Wert ökologischer Risikovorsorge, GAIA 19(2)	2010				x	x	
Single-attribute studies								
Alavalapati et al	Agroforestry development: An environmental economic perspective, Agroforestry Systems 61-62(1-2)	2004						x
Ambrey and Fleming	Valuing Ecosystem Diversity in South East Queensland: A Life Satisfaction Approach, Social Indicators Research 115(1)	2014		x				
Amigues et al	The benefits and costs of riparian analysis habitat preservation: a willingness to accept/willingness to pay contingent valuation approach, Ecological Economics 43(1)	2002						x
Anthony and Bellinger	Importance value of landscapes, flora and fauna to Tsonga communities in the rural areas of Limpopo province, South Africa, South African Journal of Science 103(3-4)	2007		x				
Asrat et al	Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption, Ecological Economics 69(12)	2010			x			
Atkinson et al	‘When to Take “No” for an Answer’? Using Entreaties to Reduce Protests in Contingent Valuation Studies, Environmental and Resource Economics 51(4)	2012						x
Baranzini et al	Tropical forest conservation: Attitudes and preferences, Forest Policy and Economics 12(5)	2010						x
Barr and Mourato	Investigating the potential for marine resource protection through environmental service markets: An exploratory study from La Paz, Mexico, Ocean & Coastal Management 52(11)	2009				x		

Bengochea et al	Análisis conjunto y espacios naturales: una aplicación al Paraje Natural del Desert de les Palmes, Forest Systems 16(2)	2007		x				
Bernard et al	Valuation of tropical forest services and mechanisms to finance their conservation and sustainable use: A case study of Tapantí National Park, Costa Rica, Forest Policy and Economics 11(3)	2009						x
Bhandari and Heshmati	Willingness to Pay for Biodiversity Conservation, Journal of Travel & Tourism Marketing 27(6)	2010						x
Bhat	Application of non-market valuation to the Florida Keys marine reserve management, Journal of Environmental Management 67(4)	2002						x
Biénabe and Hearne	Public preferences for biodiversity conservation and scenic beauty within a framework of environmental services payments, Forest Policy and Economics 9(4)	2006						x
Birol et al	Using a Choice Experiment to Estimate Farmers’ Valuation of Agrobiodiversity on Hungarian Small Farms, Environmental and Resource Economics 34(4)	2006			x			
Birol et al	Farmer preferences for milpa diversity and genetically modified maize in Mexico: a latent class approach, Environmental and Development Economics 14	2009			x			
Black et al	Valuing complex environmental goods: landscape and biodiversity in the North Pennines, Environmental Conservation 37(2)	2010				x		
Blamey et al	Valuing remnant vegetation in Central Queensland using choice modelling, Australian Journal of Agricultural and Resource Economics 44(3)	2000				x		

Boman	To pay or not to pay for biodiversity in forests - What scale determines responses to willingness to pay questions with uncertain response options?, Journal of Forest Economics 15(1-2)	2009						x
Marzetti Dall'aste Brandolini	Investing in biodiversity: The recreational value of a natural coastal area, Chemistry and Ecology 22	2006						x
Broch and Vedel	Using Choice Experiments to Investigate the Policy Relevance of Heterogeneity in Farmer Agri-Environmental Contract Preferences, Environmental and Resource Economics 51(4)	2012						x
Caparrós et al	Carbon Sequestration with Reforestations and Biodiversity-scenic Values, Environmental and Resource Economics 45(1)	2010				x		
Carlsson et al	Valuing wetland attributes: an application of choice experiments, Ecological Economics 47(1)	2003				x		
Cerda et al	Valuing biodiversity attributes and water supply using choice experiments: a case study of La Campana Peñuelas Biosphere Reserve, Chile, Environmental Monitoring and Assessment 185(1)	2013				x		
Cerda et al	Non-market economic valuation of the benefits provided by temperate ecosystems at the extreme south of the Americas, Regional Environmental Change 14(4)	2014		x				
Cesar and van Beukering	Economic Valuation of the Coral Reefs of Hawai`I, Pacific Science 58(2)	2004						x
Chan-Halbrendt et al	Hawaiian Residents' Preferences for Miconia Control Program Attributes Using Conjoint Choice Experiment and Latent Class Analysis, Environmental Management 45(2)	2010				x		

Chen and Jim	Resident Motivations and Willingness-to-Pay for Urban Biodiversity Conservation in Guangzhou (China), Environmental Management 45(5)	2010		x				
Colombo et al	Designing Policy for Reducing the Off-farm Effects of Soil Erosion Using Choice Experiments, Journal of Agricultural Economics 56(1)	2005		x				
Curtis	Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes, Ecological Economics 50(3-4)	2004						x
Desaigues and Ami	An estimation of the social benefits of preserving biodiversity, International Journal of Global Environmental Issues 1(1)	2001						x
Dikgang and Muchapondwa	The valuation of biodiversity conservation by the South African Khomani San “bushmen” community, Ecological Economics 84	2012						x
Dinis et al	Using sensory experiments to determine consumers’ willingness to pay for traditional apple varieties, Spanish Journal of Agricultural Research 9(2)	2011			x			
Do and Bennett	Estimating wetland biodiversity values: a choice modelling application in Vietnam's Mekong River Delta, Environmental and Development Economics 14(2)	2009		x				
Erwin et al	The pharmaceutical value of marine biodiversity for anti-cancer drug discovery, Ecological Economics 70(2)	2010			x			
Fleischer et al	A proactive approach for assessing alternative management programs for an invasive alien pollinator species, Ecological Economics 88	2013				x		
Garcia et al	Models for sample selection bias in contingent valuation: Application to	2009						x

	forest biodiversity, Journal of Forest Economics 15(1-2)							
García-Llorente et al	Social perceptions of the impacts and benefits of invasive alien species: Implications for management, Biological Conservation 141(12)	2008					x	
Garcia-Yi	Identification of Dried Native Chili Markets in the International Tourism Sector in Peru: An Open-Ended Contingent Valuation Study, Sustainability 6(2)	2014			x			
Garrod and Willis	Valuing biodiversity and nature conservation at a local level, Biodiversity & Conservation 3(6)	1994						x
Garrod and Willis	The non-use benefits of enhancing forest biodiversity: A contingent ranking study, Ecological Economics 21(1)	1997	x					
Gavin and Anderson	Testing a rapid quantitative ethnobiological technique: First steps towards developing a critical conservation tool, Economic Botany 59(2)	2005				x		
Glenk and Colombo	Designing policies to mitigate the agricultural contribution to climate change: an assessment of soil based carbon sequestration and its ancillary effects, Climatic Change 105(1-2)	2011						x
Halkos and Jones	Modeling the effect of social factors on improving biodiversity protection, Ecological Economics 78	2012						x
Hasund et al	Valuing public goods of the agricultural landscape: a choice experiment using reference points to capture observable heterogeneity, Journal of Environmental Planning and Management 54(1)	2011	x					
Heberlein et al	Rethinking the scope test as a criterion for validity in contingent valuation, Journal of Environmental Economics and Management 50(1)	2005				x		
Horne	Forest owners' acceptance of incentive based policy instruments in forest	2006						x

	biodiversity conservation - A choice experiment based approach, Silva Fennica 40(1)							
Horne et al	Multiple-use management of forest recreation sites: a spatially explicit choice experiment, Forest Ecology and Management 207(1-2)	2005		x				
Hoyos et al	Valuing a Natura 2000 network site to inform land use options using a discrete choice experiment: An illustration from the Basque Country, Journal of Forest Economics 18(4)	2012		x				
Itsubo et al	Weighting across safeguard subjects for LCIA through the application of conjoint analysis, The International Journal of Life Cycle Assessment 9(3)	2004				x		
Jacobsen et al	What's in a name? The use of quantitative measures versus 'Iconised' species when valuing biodiversity, Environmental and Resource Economics 39(3)	2008				x		
Jacobsen et al	Embedding effects in choice experiment valuations of environmental preservation projects, Ecological Economics 70(6)	2011				x		
Jacobsen et al	Valuation of wildlife populations above survival, Biodiversity and Conservation 21(2)	2012				x		
Jorgensen et al	Fairness in the contingent valuation of environmental public goods: attitude toward paying for environmental improvements at two levels of scope, Ecological Economics 36(1)	2001						x
Juutinen et al	Combining ecological and recreational aspects in national park management: A choice experiment application, Ecological Economics 70(6)	2011				x		

Kaffashi et al	Economic valuation and conservation: Do people vote for better preservation of Shadegan International Wetland?, Biological Conservation 150(1)	2012				x		
Khai and Yabe	Choice modeling: assessing the non-market environmental values of the biodiversity conservation of swamp forest in Vietnam, International Journal of Energy and Environmental Engineering 5(1)	2014		x				
Koellner et al	Why and how much are firms willing to invest in ecosystem services from tropical forests? A comparison of international and Costa Rican firms, Ecological Economics 69(11)	2010						x
Kolahi et al	From Paper Parks to Real Conservations: Case Study of Social Capital in Iran’s Biodiversity Conservation, International Journal of Environmental Research 8(1)	2014						x
Kragt et al	Effects of Great Barrier Reef degradation on recreational reef-trip demand: a contingent behaviour approach, Australian Journal of Agricultural and Resource Economics 53(2)	2009						x
Krishna et al	Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries, Ecological Economics 87	2013			x			
Lindhjem and Mitani	Forest owners’ willingness to accept compensation for voluntary conservation: A contingent valuation approach, Journal of Forest Economics 18(4)	2012						x
Lindhjem and Navrud	Asking for Individual or Household Willingness to Pay for Environmental Goods?, Environmental and Resource Economics 43(1)	2009						x

Hatton MacDonald and Morrison	Valuing biodiversity using habitat types, Australasian Journal of Environmental Management 17(4)	2010						x
Maharana et al	Valuing ecotourism in a sacred lake of the Sikkim Himalaya, India, Environmental Conservation 27(3)	2000						x
Martin and Blossey	Invasive plant cover impacts the desirability of lands for conservation acquisition, Biodiversity and Conservation 21(8)	2012				x		
Martín-López et al	The non-economic motives behind the willingness to pay for biodiversity conservation, Biological Conservation 139(1-2)	2007				x		
McVittie and Moran	Valuing the non-use benefits of marine conservation zones: An application to the UK Marine Bill, Ecological Economics 70(2)	2010	x					
Merganic et al	Relationship between biodiversity indicators and its economic value - case study, Periodicum Biologorum 115(3)	2014					x	
Meyerhoff et al	Valuing the benefits of implementing a national strategy on biological diversity—The case of Germany, Environmental Science & Policy 23	2012						x
Mitani et al	Estimating economic values of vegetation restoration with choice experiments: a case study of an endangered species in Lake Kasumigaura, Japan, Landscape and Ecological Engineering 4(2)	2008				x		
Morlando et al	Reduction in Lyme Disease Risk as an Economic Benefit of Habitat Restoration, Restoration Ecology 20(4)	2011						x
Morse-Jones et al	Ecosystem valuation: some principles and a partial application, Environmetrics 22(5)	2012				x		
Muriithi and Kenyon	Conservation of biodiversity in the Arabuko Sokoke Forest, Kenya, Biodiversity and Conservation 11(8)	2002						x

Murillas-Maza et al	The value of open ocean ecosystems: A case study for the Spanish exclusive economic zone, Natural Resources Forum, UN 35(2)	2011						x
Mwebaze et al	Economic valuation of the influence of invasive alien species on the economy of the Seychelles islands, Ecological Economics 69(12)	2010				x		
Naidoo and Adamowicz	Biodiversity and nature-based tourism at forest reserves in Uganda, Environment and Development Economics 10(2)	2005				x		
Ninan and Sathyapalan	The economics of biodiversity conservation: a study of a coffee growing region in the Western Ghats of India, Ecological Economics 55(1)	2005				x		
Polak and Shashar	Economic value of biological attributes of artificial coral reefs, ICES Journal of Marine Science 70(4)	2013			x			
Poudel and Johnsen	Valuation of crop genetic resources in Kaski, Nepal: Farmers' willingness to pay for rice landraces conservation, Journal of Environmental Management 90(1)	2009			x			
Raboteur and Rodes	Application de la méthode d'évaluation contingente aux récifs coralliens dans la Caraibe : étude appliquée à la zone de Pigeon de la Guadeloupe, VertigO 7(1)	2006						x
Rees et al	The value of marine biodiversity to the leisure and recreation industry and its application to marine spatial planning, Marine Policy 34(5)	2010						x
Ressurreição et al	Economic valuation of species loss in the open sea, Ecological Economics 70(4)	2011		x				
Rodríguez-Entrena et al	Evaluating the demand for carbon sequestration in olive grove soils as a strategy toward mitigating climate change, Journal of Environmental Management 112	2012		x				

Rogers et al	The inclusion of non-market values in systematic conservation planning to enhance policy relevance, Biological Conservation 162	2013				x		
Rolfe et al	Valuing the preservation of rangelands: Tree clearing in the desert uplands region of Queensland, The Rangeland Journal 22(2)	2000				x		
Sattout et al	Economic value of cedar relics in Lebanon: An application of contingent valuation method for conservation, Ecological Economics 61(2-3)	2007						x
Schuhmann et al	Recreational SCUBA divers' willingness to pay for marine biodiversity in Barbados, Journal of Environmental Management 121	2013		x				
Shoyama et al	Public preferences for biodiversity conservation and climate-change mitigation: A choice experiment using ecosystem services indicators, Land Use Policy 34	2013				x		
Spash	Informing and forming preferences in environmental valuation: Coral reef biodiversity, Journal of Economic Psychology 23(5)	2002	x					
Spash et al	Motives behind willingness to pay for improving biodiversity in a water ecosystem: Economics, ethics and social psychology, Ecological Economics 68(4)	2009	x					
Stevens et al	Public attitudes and economic values for wetland preservation in New England, Wetlands 15(3)	1995				x		
Stithou and Scarpa	Collective versus voluntary payment in contingent valuation for the conservation of marine biodiversity: An exploratory study from Zakynthos, Greece, Ocean & Coastal Management 56	2012				x		
Subade	Mechanisms to capture economic values of marine biodiversity: The case of Tubbataha Reefs UNESCO World Heritage Site, Philippines,	2007						x

	Marine Policy 31(2)							
Subade and Francisco	Do non-users value coral reefs?: Economic valuation of conserving Tubbataha Reefs, Philippines, Ecological Economics 102	2014						x
Surendran and Sekar	An economic analysis of willingness to pay (WTP) for conserving the biodiversity, International Journal of Social Economics 37(8)	2010						x
Susaeta et al	Assessing Public Preferences for Forest Biomass Based Energy in the Southern United States, Environmental Management 45(4)	2010	x					
Szabó	Reducing protest responses by deliberative monetary valuation: Improving the validity of biodiversity valuation, Ecological Economics 72	2011	x					
Travisi and Nijkamp	Valuing environmental and health risk in agriculture: A choice experiment approach to pesticides in Italy, Ecological Economics 67(4)	2008				x		
Turpie	The existence value of biodiversity in South Africa: how interest, experience, knowledge, income and perceived level of threat influence local willingness to pay, Ecological Economics 46(2)	2003						x
Turpie et al	Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies, Biological Conservation 112(1-2)	2003			x			
Van Beukering et al	Economic valuation of the Leuser National Park on Sumatra, Indonesia, Ecological Economics 44(1)	2003						x
Veisten et al	Scope insensitivity in contingent valuation of complex environmental amenities, Journal of Environmental Management 73(4)	2004				x		
Veisten et al	Lexicographic Preference in Biodiversity Valuation: Tests of	2006						x

	Inconsistencies and Willingness to Pay, Journal of Environmental Planning and Management 49(2)							
Vergano and Nunes	Analysis and evaluation of ecosystem resilience: an economic perspective with an application to the Venice lagoon, Biodiversity and Conservation 16(12)	2007					x	
Wang and Jia	Tourists’ willingness to pay for biodiversity conservation and environment protection, Dalai Lake protected area: Implications for entrance fee and sustainable management, Ocean & Coastal Management 62	2012						x
Wätzold et al	Estimating optimal conservation in the context of agri-environmental schemes, Ecological Economics 68(1-2)	2008				x		
Xu et al	Valuing Biodiversity, Aesthetics, and Job Losses Associated with Ecosystem Management Using Stated Preferences, Forest Science 49(2)	2003		x				
Westerberg et al	To restore or not? A valuation of social and ecological functions of the Marais des Baux wetland in Southern France, Ecological Economics 69(12)	2010				x		
Willis and Garrod	Biodiversity values for alternative management regimes in remote UK coniferous forests: an iterative bidding polychotomous choice approach, Environmentalist 18(3)	1998						x
Wossink and van Wenum	Biodiversity conservation by farmers: analysis of actual and contingent participation, European Review of Agricultural Economics 30(4)	2003						x
Wüstemann et al	Financial costs and benefits of a program of measures to implement a National Strategy on Biological Diversity in Germany, Land Use Policy	2014						x

	36							
Xu et al	Assessment of indirect use values of forest biodiversity in Yaoluoping national nature reserve, Anhui province, Chinese Geographical Science 13(3)	2003					x	
Yao et al	Valuing biodiversity enhancement in New Zealand's planted forests: Socioeconomic and spatial determinants of willingness-to-pay, Ecological Economics 98	2014				x		
Xue and Tisdell	Valuing ecological functions of biodiversity in Changbaishan Mountain Biosphere Reserve in Northeast China, Biodiversity & Conservation 10(3)	2001					x	

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