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„Awareness of the value of Biodiversity: A questionnaire study with University students from different educational backgrounds“

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Contents

1 Acknowledgements

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2 Abstract

Scientific evidence for the importance of biodiversity to sustain ecological functioning and to secure ecosystem services, which are essential to human survival and well-being, has been growing substantially during the last two decades. Although more theoretical and experimental work needs to be done to unravel the mechanisms behind the observed links between biodiversity and ecosystem functioning, calls for dedicated action are getting louder as we face human-induced biodiversity loss, nearly as severe as it was during the five big mass extinctions in Earth's history. Central to mitigating the causes and adapting to the consequences of biodiversity loss are: interdisciplinary communication and work between scientists from different domains together with policy makers, promoting public education and participation thereby raising awareness, and further studying the phenomena to fine-tune actions. A working conception of the value of biodiversity is a necessary prerequisite for all management schemes. My research will deal with these dimensions of managing the complexity of biodiversity loss. Empirical findings will hopefully reflect this multi-dimensional approach in different groups of students and provide a basis of recommendations for promising courses of action.

3 Introduction

According to the Stanford Encyclopedia of Philosophy biodiversity "is often defined as the variety of all forms of life, from genes to species, through to the broad scale of ecosystems" (Faith, 2008). TEEB [1] defines the term as: "Biodiversity reflects the hierarchy of increasing levels of organization and complexity in ecological systems." (in (Kumar, 2010) Chapter 2, p.45), Hooper et al. (2005) (p.5) state that: "Biodiversity can be described in terms of entities [...], the evenness of their distribution, the differences in their functional traits, and their interactions."

We can clearly see that biodiversity is not easily definable in only a few words. All of the definitions above are of coarse nature and they encompass a wide variety of interrelated terms like: variation, hierarchy and functionality. Although the term biodiversity is often used in science as well as in policy making, it seems to be vague. Literature tells us that (public) understanding and awareness of biodiversity-related issues is incomplete if even

[1] The Economics of Ecosystems and Biodiversity, see section 5.1

existent (Novacek, 2008; Lindemann-Matthies and Bose, 2008). But before discussing the implications of knowledge production concerning biodiversity we must take a step back and look at why biodiversity is such an important environmental asset to begin with. What role does it play in the functionality of ecosystems around the planet and how do humans benefit from conserving existing diversity?

I tried to depict the central features of the problem of biodiversity loss, with the different dimensions involved, in figure 1. Though the pressure-factors labeled 'anthropogenic' and 'environmental' are heavily interlinked and often cannot be differentiated at all, this dichotomy was included to visualize the problem-synergies that arise when human action coincides with environmental change. Pressure on ecosystems leads to the loss of biodiversity and the benefits these systems provide for human well-being. Different scientific disciplines contribute to the creation of regulatory regimes, through the gathering and interpretation of information concerning the causes and consequences of the change in ecosystem functioning. Regulation is mostly triggered towards directly conserving vulnerable species and habitats by shielding them against human influence. This battle against symptoms is much more common than regulation of the way we humans influence nature through our economic behavior, in the graphic depicted through the dashed line.

This thesis is structured according to the visualization. It will explain the importance of biodiversity in the provision of benefits for us humans and show how pressure on ecosystems is threatening the provision of these benefits. It will contain information from the three scientific clusters and, subsequently, a mix of ideas for regulatory regimes that may help to fight against biodiversity loss.

In the first part I will draw on recent publications from the ecological sciences to subsume the consensus concerning the importance of biodiversity. In the following second part I will try to highlight some ways economics has dealt with the problem of biodiversity loss and present a methodology of valuing ecosystem services. The third part will contain different management approaches, that may help to deal with biodiversity loss. It will be a mix of potential difficulties and ways to surpass them. The final part will include the empirical findings from a questionnaire study with university students, surrounding the topics of the three theoretical parts. (Lindemann-Matthies and Bose, 2008) stated that "[a]t present hardly anything is known about what lay people [...] consider meaningful contributions to preserve biodi-

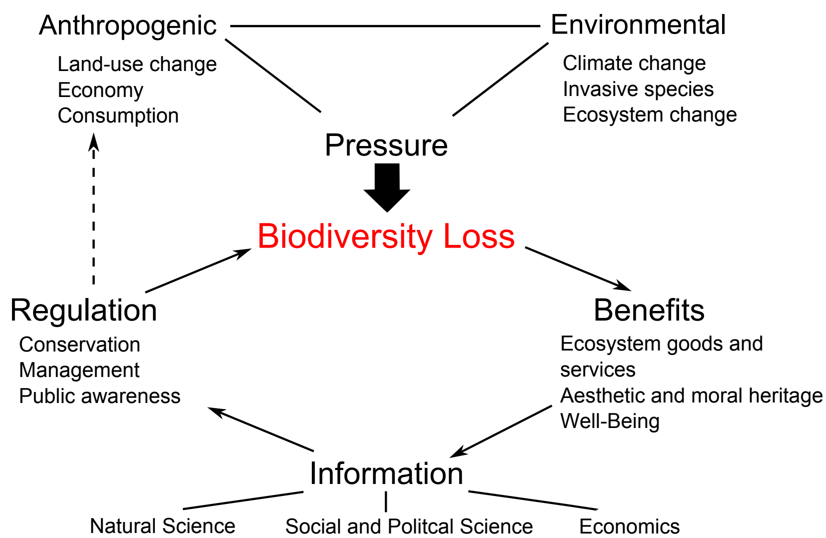

Figure 1: Heuristic visualization of the "Biodiversity Loss" problem

versity and what they are actually willing to contribute" (ibid., p. 740). I hope to shed some light on this question with this work.

4 Background - Ecology

Research on biodiversity is a rather young area of interest in ecology. It only spread widely at the beginning of the twenty first century (Faith, 2008). But since then it developed into a subject of ever growing interest. A lot of research, both of theoretical and of empirical nature was conducted, and a bunch of people invested a lot of time into untangling the connections between viability and organismic composition in different ecosystems around the globe. The following paragraphs will present a collection of scientific literature about the most important findings of the last decade of research on biodiversity. I will focus on the consensus view and highlight some points of ongoing dispute in the field. The following preliminary summary is based on Hooper et al. (2005).

4.1 Biodiversity and ecosystem functioning

It is an established fact that some functional characteristics of species strongly influence ecosystem properties, which were defined as size of compartments and rates of processes in ecosystems. Consequently ecosystem properties are changing with alternating biotic composition, with different responses in different ecosystems. Further this has an influence on ecosystem goods, which have direct market value and ecosystem services, which directly or indirectly support human well-being. Ecosystem goods and services can only be sustained if the species pool is big enough to respond to varying environmental conditions. Taken together ecosystem properties, goods and services will go under the name of ecosystem functioning, following the terminology proposed by Hooper et al. (2005) (p.7). There are different theories explaining potential mechanisms underlying the relationship between biodiversity and ecosystem functioning. Let us first deal with the magnitude of ecosystem properties. (Hooper et al., 2005).

4.1.1 Biodiversity and ecosystem productivity

One effect of higher levels of biodiversity could be the subsequent increase in ecosystem productivity, either because of what is called the 'sampling effect', which describes the statistically higher chance of having an influential species in the species pool simply if the overall number of species is greater, or because of complementarity and facilitation between species through better use of ecological niches. Both mechanisms lead to greater productivity of the ecosystem, whereas a saturation occurs at a certain point between increasing number of species and ecosystem productivity. Some scientist claim that sampling effects do not have a significant relevance in natural ecosystems, because these systems are in fact not a random assemblage of species, as assumed in many experiments. If sampling effects do play a role it is not said that they work in an antagonistic way to complementarity phenomena. Ecosystem response takes place on a continuum with these two mechanisms producing extreme situations at both ends. In addition to the interactions, described above, between species richness and ecosystem functioning, including more than just one trophic level (often the primary focus of experimental studies) adds an enormous amount of complexity to the research.

Experimental research has more or less confirmed the hypothesis above with the main outcome that there is a huge amount of variation in the relationship between species richness and composition, and different forms of ecosystem response depending on interactions between complementarity and sampling effects, functional traits of involved species, and variability in environmental conditions. (Hooper et al., 2005).

In any case richness and composition of the species pool has a significant influence on the productivity of the ecosystem and on other ecosystem functions. These claims relate to 'natural' or 'pristine' ecosystems. Ecosystems heavily manipulated by human action like intensive crop monocultures, show high productivity at low levels of diversity. This productivity though is only sustained through high levels of energy (i.e. fertilizer, water, biocides) input and these intensive agricultural systems are generally neither environmentally nor economically sustainable (Kumar (2010) Chapter 2, p.52).

The other main ecosystem function, namely ecosystem stability will be the topic of the next section.

4.1.2 Biodiversity and ecosystem stability

Theoretical work supposes that ecosystem stability, meaning stability of ecosystem properties, increases with increasing diversity. Stability in this case refers to two different phenomena. It can either mean resistance to disturbance or resilience to disturbance, the ability of the system to retain central parameters of functionality and return to an initial state of equilibrium after a shock. The concept of resilience will be dealt with more exhaustively later (see section 6.5).

Redundancy in ecological effect traits of species is one of the main reasons why greater diversity leads to more stable ecosystem properties. If more than just one species is exhibiting a certain ecological function then, also if one of these species becomes extinct, the function will still be carried out by the other, even if not in the same scale of speed or magnitude. This phenomenon is also termed the 'insurance hypothesis' (Scherer-Lorenz, 2005).

The second important mechanism is diversity in ecological response traits of species. The greater the variety of responses to a certain environmental stress or constrain the lower the likelihood that eventually all species performing a certain ecological function will become extinct, which is also know as the 'portfolio effect'.

Although mathematical models do generally agree with the hypothesis above, further refinement of the models and more experimental confirmation is needed. (Hooper et al., 2005).

As an additional remark it should be said that species richness must increase with increasing spatial and temporal scale to maintain ecosystem properties. This is likely to have great importance in the face of a global biodiversity crisis (Costanza et al., 2007; Djoghlaf and Dodds, 2011).

Experimental work on these hypothesis, though complex and complicated, has come up if some points of consensus: Divers communities can buffer their functionality against changing environmental conditions and species loss. Also was greater resilience observed when a higher diversity of ecological response traits was present in the community. (Hooper et al., 2005).

Still it must be said that idiosyncratic patterns of community response are often observed due to traits of keystone species or ecosystem engineers (Scherer-Lorenz, 2005), which have a disproportionately large effect on ecosystem functioning, meaning that the loss of one of such species will result in a far greater impact on ecosystem functioning (Kumar (2010) Chapter 2).

Other factors, like evolutionary adaptation to certain kinds of disturbances, play major roles in species and community response to environmental fluctuations. Taking counterexamples into consideration suggests that diversity alone does not automatically support stability if the right combination of functional traits is not present (Hooper et al., 2005). But higher levels of biodiversity can still function as a reservoir of ecological traits that could eventually be important in the face of environmental change in the future. In addition to that not all important functional traits of species in all the different ecosystems are yet known, which means that in order to be best equipped for change it would help maintaining levels of high diversity precautionary (McCann, 2000). Loreau et al. (2001) sum up the importance of biodiversity in maintaining ecosystem functioning as follows: "There is consensus that at least some minimum number of species is essential for ecosystem functioning under constant conditions and that a larger number of species is probably essential for maintaining the stability of ecosystem processes in changing environments." (ibid., p. 807). In any case much more experimental work needs to be done in order to strengthen the evidence behind the hypothesis, as uncertainty about biodiversity effects on landscape level, and across ecosystems remains.

In the preceding paragraphs I have presented the scientific consensus on how biodiversity affects ecosystems. Questions still remain: why should a stable or healthy functioning of ecosystem be of concern for human well-being? And: What exactly are the ecosystem goods and services we depend upon and how is the provision of these services threatened by the high rates of biodiversity loss we are currently facing (Rockström et al., 2009)? Coverage of these questions will be the purpose of the following section, which is based on Kumar (2010), Chapter 2.

4.2 Biodiversity and ecosystem services

Defining quantitative links between biodiversity and ecosystem services is a complex task mainly because of three points: First, biodiversity is a concept that encompasses many different scales and dimensions, it reaches from biome to gene levels and it subsumes phenomena like functional trait diversity, phylogenetic diversity, webs of interaction and others. Second, biodiversity data are very variable and the main focus of most experiments does not lie on ecosystem services. The third problem is that the measure of biodiversity that serves to clarify the connection to a certain ecosystem service, is different for almost every different ecosystem service. Because of these complications it is "not yet possible to account accurately for the role of biodiversity, nor the probable impact of its decline, on ecosystem service delivery in general." (Kumar (2010) Chapter 2, p.55). Evaluating the importance of biodiversity in the provision of ecosystem services is therefore always a context-sensitive process. Even if the underlying mechanisms are still largely unknown there are numerous ecosystems services which correlate with levels of biodiversity, though in different magnitudes. Examples are divided into four classes:

1. Provisioning services which contain: food, water, fuels and fibers, genetic resources, medicinal and other biochemical resources, and ornamental resources.

2. Regulating services which contain: air and urban environmental quality, climate regulation, moderation of extreme events, erosion prevention, maintenance of soil quality, pollination services and biological control.

3. Habitat services which contain: maintenance of life cycles of migratory species and maintenance of genetic diversity.

4. Cultural and amenity services which contain: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development.

Detailed information about every single of these services can be found in Kumar (2010) Chapter 2.

4.3 Threats to biodiversity

In the preceding sections I have discussed the important role biodiversity plays in the functionality of ecosystems. What implications that has on human well-being will be topic of section 4.6. I have mentioned above that we are currently facing high levels of biodiversity loss (see Rockström et al. (2009) and Djoghlaf and Dodds (2011)), but it is interesting to uncover and differentiate the drivers that cause these high levels of species extinction. This will be the topic of the following paragraphs.

Chapter 1 in Djoghlaf and Dodds (2011) is based on the conceptual framework of the Millennium Ecosystem Assessment 2005 and provides a comprehensive overview of the drivers that cause change (positive or negative) in levels of biodiversity. Drivers can either be of natural or of human origin, they can also be classified into direct versus indirect, and endogenous versus exogenous. Indirect drivers, like growing demand for meat, influence the direct drivers, like conversion of rainforest to pasture land. Endogenous drivers are those that can be controlled by decision-makers in question, exogenous drivers are out of their control.

The most important indirect drivers are:

- *Economic growth, demographic change and behavior change*, which are often accompanied with increasing demand for natural resources.

- *Advances in science and technology*, which are in the moment going into the direction of more efficiency. Intensification of agriculture is one example, with all the adverse impacts it has on local biodiversity (see Reidsma et al. (2006)).

- *Socio-political changes*, which are of course very different on a global scale. But democratization tends to be coupled with the development of market-based economies, and enhanced international communication may lead to better cooperation to preserve environmental resources.

These drivers in turn have a significant influence on the direct drivers:

- *Conversion and fragmentation of natural habitats*, mostly through land-use change via clearing of areas for agricultural and pasture land. Conversion is especially problematic in species- and endemism-rich ecosystems. Fragmentation often negatively influences dispersal abilities of species, which are then more vulnerable to extinction. These were defined to be the most influential drivers over the last 50-100 years (see also Sala et al. (2000)).

- Followed by *Introduction of exotic invasive species*, due to global transport regimes. Introductions often have negative impacts on local communities of species and ecosystems.

- The driver with the third largest impact is *Overexploitation*, mainly of marine species through fishing, hunting of bush meat, pet trade, and harvesting of medicinal plants.

- Other drivers are *Pollution of air, land and water* and *Climate change*, which are projected to become more important in the near future.

A similar enumeration of drivers, which also treats the role of species community structure and global biogeochemical cycles, can be found in Novacek and Cleland (2001). It should be noted that the drivers do not act independently of each other and it is important to consider synergies and/or feedbacks in the context of different management projects. It is clearly visible that the biggest player in driving change in ecosystems and biodiversity are we humans. Of course alteration of habitats does also happen naturally, in the course of wild fires, volcanic eruptions, floods, and so on. But these events are mostly not comparable to the scale of human modification and are definitely more stochastic and scarce, compared to steady and ongoing, even accelerating human influence.

The drivers lead to extinction of species in their natural habitats. It seems straight forward to calculate biodiversity loss via species extinction, but there are debates whether or not estimates in that respect represent good approximations and whether we under- or overestimate the current loss of species. More of that in section 4.5.

Just how much of the world's biodiversity is being lost, in recent times and in the near future is topic of the next section.

4.4 Diversity lost

Ecosystem services provide a basis for human survival on this planet and evidently biodiversity plays a central role in the stable provision of these services. Still up to date environmental policy and management have failed to avert the ongoing loss of biodiversity (Djoghlaf and Dodds, 2011), which is happening at an alarming speed since the advent of the so called Anthropocene, the geological epoch that we are living in momentarily and that is largely dominated by human action, through our influence on physical and biogeochemical processes on a global scale (Crutzen, 2002). The rate at which species become extinct in the moment is between 100 to 1000 times higher than the natural background rate, determined by fossil records. This rate exceeds the rate of speciation by far and is expected to rise another ten-fold during the next century. It is widely acknowledge that human action is the main driver here. (Pimm et al., 1995; Rockström et al., 2009).

Biodiversity loss has become a global change phenomenon in itself (Sala et al., 2000) that threatens human well-being on multiple levels, as we loose all different kinds of services and the insurance value of ecosystems for the future (Diaz et al., 2006).

Despite of the effort to significantly reduce the rate of biodiversity loss until the year 2010, which was formulated through the Convention on Biological Diversity in 2002, biodiversity continued to decline with stable rates, whereas extinction risk and indicators of pressure increased. Although indicators of management and policy showed positive trends, meaning for example the number of countries that have set in motion national biodiversity strategies rose, as well as the extent of protected areas, it is highly unlikely that the CBD target has been met on a global scale (Butchart et al., 2010).

A discussion on the role of species extinction, often the main indicator used for defining rates of biodiversity loss is the topic of the next section.

4.5 Discussions on the role and magnitude of species extinctions

Extinction of species is per se a natural phenomenon. Because of human action the rate of extinctions has been accelerating considerably in the last 50 - 100 years. It is estimated that until the mid of the 21st century 30% of all known species will have gone into extinction, with most of the loss happening in tropical rainforests and marine ecosystems. It was stated that if this estimates are found to be true, this would drastically reconfigure if not reset the future evolution of species on this planet (Novacek and Cleland, 2001). Current extinction rates exceed those that caused the 'Big Five' extinctions in Earth history. Even if we have not yet reached a level of biodiversity loss high enough to qualify for a mass extinction in the moment, there are clear signs that we will enter such an extinction event if we loose the species which were defined as 'critically endangered'. Although this might still take about 1000 years, it could go faster (in times of a few centuries), if we loose additional species considered 'endangered' or 'vulnerable'. This might still seem a long time away, but we are really just talking about a few generations. Together with factors of climate change and other global change phenomena the potential for a 'perfect storm', similar to past extinction events, is high. (Barnosky et al., 2011).

Biodiversity is heavily interlinked with ecosystem functioning and consequently with economic wealth and human well-being. The current loss rates have made it a global change phenomenon on itself, but with large variations across biomes (Sala et al., 2000; Jenkins, 2003).

There are 25 "hotspots" around the globe, which make up for only about 2% of the land surface area and where biodiversity and endemism is disproportionally high. The hotspots dominate the global pattern of extinction, mainly because of the high number of endemic species found within these regions (Pimm et al., 1995). These regions, especially the tropical humid forests, are already under enormous pressure, because of rapid ongoing habitat destruction. There is a non-linear relationship between the size of these "islands" of high biodiversity and the number of species they contain. The relationship of number of species to area together with estimates of habitat loss and species survivorship make it possible to calculate a crude extinction curve that can be extrapolated into the future. On average it seems that we will loose few species in the near future and many more in the more distant future. The loss will peak with a five-fold increase in species extinctions in 2060 (10 000 extinctions per million species per decade today - 50 000 in 2060). This number was calculated for tropical forests. If this framework is applied without considering the hotspots, it is calculated that we would still be able to protect 50% of the species if only 5% of the area remains. But if a closer look is taken into the development of the hotspots, the conclusion is that if the rates of habitat loss, documented in the year 2000, remain constant for another decade (which means until 2010 - see reference), we will eventually loose 40% of the species in the hotspots. This situation is problematic at least, as these hotspots contain roughly 30-50% of the total number of known plant, amphibian, reptile, mammal and bird species. An additional problem is that the area of primary vegetation has been severely reduced in the hotspots and has come down to 12% of the original. (Pimm and Raven, 2000).

The upside is that a lot can be done by protecting these rather small areas, but this remains a challenge, mainly because of conflicting interests between regional economies and conservation efforts. And though local protection may secure resources for bioprospection and genetic potential, it may not be enough to ensure stable provision of ecosystem services on a global scale.

Jenkins (2003) notes that calculating and extrapolating extinction rates and extinction risk is difficult and surrounded by uncertainties. Exact data are not very abundant. According to Jenkins, loss of biodiversity is currently no threat to human survival. Other authors take a bit more precautionary position and argue that the current extinction of species has the potential of leading to the crossing of systemic thresholds and reaching critical tipping points in the Earth system, with possible undesired consequences (Rockström et al., 2009). Rockström also admits that extinction rates are problematic as an indicator, because they do not give information about the relative functional importance of species. As long as there is no workable alternative though, this indicator will have to serve as a proxy. In face of the magnitude and speed of change, that was documented over the course of the last decades (Pimm et al., 1995), it is not unrealistic to expect that we still underestimate the role of species extinctions. I have also noted above that it is not a fancy to consider all species in an ecosystem important, especially if we have not yet uncovered the functional role of every species (McCann, 2000).

There was a very recent discussion going on whether calculating species extinction using species to area relationships is adequate. Generally the number of species increases with the area sampled. Reversing this curve allows one to estimate the number of species lost when the area is reduced. Some authors state that this methodology will eventually lead to overestimations of realistic extinction numbers. In a technical sense this may be true, but in a very convincing response to that publication, Mark Thompson stated that species extinction should not exclusively lie at the heart of the biodiversity crisis. Ecosystem services should be a main focus instead, and they do also rely on population densities and dispersal. Even if a species does not go extinct with altered habitats, it may well be that the reliability on the function this species has in the ecosystem is reduced, thereby reducing the resilience of the whole system. (Rahbek and Colwell, 2011; Brooks, 2011).

As we have seen, species extinction is a discussed indicator for biodiversity loss. It is clearly not an omnipotent one and it has methodological drawbacks. But we need indicators to show and compare the development of different ecosystems. Context and scale are two important parameters that should be included in every study. Ecosystems influence human well-being on very different levels. A small patch of adjacent forest hosts the insects that pollinate the vegetables and flowers in our home garden and at the same time a natural living forest regulates climate and precipitation thousands of kilometers away. Makarieva and Gorshkov (2007) have shown that large areas of forest cover surrounding river basins in connection with oceans drive a biotic water pump, that is needed to ensure the transport of water to inland ecosystems. The Amazon and Congo basins but also northern basins in Russia and Canada, which are densely forested, can support the biotic water pump only when they remain in an undisturbed natural state and span areas large enough.

To rely on a single unit of measurement in that respect, is probably shortsighted, but as long as we have not come up with a superior one, species extinction will have to do. Also it seems reasonable to use extinction numbers and their change over time as a proximate to show just how great human impact is on ecosystems. There is no doubt that science provides us with vital information about the problem, but mitigating only the extinction of species in biodiversity hotspots won't be enough to solve it. An compelling case for the conservation of Antarctic dry valley ecosystems, which show very low biodiversity, was given by Wall (2007). She found in her studies that regions with low diversity are especially vulnerable to global change, what is obvious because the whole of the few species living in these extreme environments may become extinct much quicker than in highly divers systems. This fact is also due to the narrow set of environmental and climatic conditions that species in those areas have adapted to, which makes them more sensitive to minor changes. This in turn leads to changes in the dynamics of the local ecosystem. In the same time low-diversity systems constitute the functionality of ecosystems in a very large geographical area, with feedbacks both to terrestrial and marine systems.

We can see that species richness alone is not the only ingredient in the formula that ensures stable provision of ecosystem benefits to human well-being. What is particularly important are the relations amongst species and between species and their environment. Also the dynamics of whole ecosystems and feedbacks between ecosystems must be taken into account. A cardinal concern is the non-linear behavior of such systems which may lead to sudden flips in their functioning and respectively in service provision. This happens when certain thresholds are crossed and the system reaches a tipping point. Species loss is definitely a driver here, but in a holistic sense, the whole is greater than the sum of its parts. A review of the theory of adaptive systems in the face of (imposed) change is the topic of section 6.5.

Now before I discuss different management possibilities to deal with the problem of biodiversity loss, their differences and similarities, weaknesses and strengths, I will review some chapters of *Biodiversity, Ecosystem Functioning, & Human Wellbeing* (Naeem et al., 2009) to consolidate the basic evidence from natural science and to draw the bridge to the value of biodiversity for human well-being.

4.6 The Biodiversity - Ecosystem Functioning framework and human well-being

The influential paper from Hooper et al. (2005) depicts the consensus of scientific evidence on the relation between biodiversity and ecosystem functioning from an ecological point of view. Following work by Naeem et al. (2009) explicitly puts the biodiversity ecosystem functioning (BEF) framework in the context of human well-being. This section is a review of their work.

The authors argue that the next logical step after a period of fruitful research on BEF relationships must be to compile, translate, and transform the central messages of numerous studies to inform society and policy makers. Only in this way a working agenda can be installed, that is needed to successfully ensure the continuing provision of ecosystem services, which in turn provide the natural basis for sustainable development. The integration of this approach into basic ecological "textbook-knowledge" has not yet been achieved properly, mainly because of the relative "messiness" of the BEF framework in comparison to "pure" ecological theory (e.g. population and community ecology). This situation is probaly due to the complexity and multiplicity of BEF theories. Therefore Naeem et al. (2009) have produced a comprehensive textbook, which provides us with a meta-perspective on a bulk of evidence from numerous studies, elucidates the importance of the link between BEF theory and human well-being in different case studies, and concludes with thoughts and suggestions that go far beyond the scope of traditional ecology. To be up to date with current advances in the field, parts of the book will now be reviewed.

In the introductory first chapter Naeem et al. (2009) state, that only an interdisciplinary approach can help to cope with the problem of biodiversity loss. Ecologists and economists should work together creating synergies to mitigate the dramatic loss of taxonomic richness, which drops to about 10% - 1% of the original value, when complex ecosystems are transformed into managed systems. This leads to a loss of functional trait diversity. Given that only high levels of biodiversity can ensure the provision of multiple ecosystem functions or services, that in turn critically undermines stability and reliability of those ecosystem services.

The authors also come to the unwelcome conclusion, that whereas the scientific community concerned with the BEF framework is strong and growing, "there is little evidence [...] that biodiversity conservation as a route to improve human well-being has become a strong part of private or public consciousness." (Naeem et al. (2009), p. 11-12).

In chapter 2 the authors perform two meta-analysis of a large amount of data and come to the following conclusions:

- Biodiversity effects vary between ecosystem types, generalizing is therefore limited.

- Increasing biodiversity positively affects responses at community and ecosystem level, but negatively affects responses at population level. This is not surprising, because with increasing diversity any input into the system will be distributed over more and more species and response on population level will therefore decrease, on average.

- Biodiversity has different influences on stocks versus rates in ecosystems.

- Higher biodiversity on one trophic level has negative effects on functions on adjacent trophic levels (top-down and bottom-up), but a positive effect on functions on the same level (except for detrivore communities). The theory behind this is straightforward, because a more divers community is more resistant to predation and disease (negative bottom-up effect), and in the same time is able to use available resources more completely (negative top-down effect).

- Higher biodiversity has positive effects on the resident community, but negative effects on invaders.

These hypothesis were confirmed by the meta-analysis from experimental data, but applying these findings to real-world situations remains a challenge, because the mechanisms behind the processes are yet to be discovered. Still the high number of data derived from various studies implies that the findings are very robust.

In chapter 3 the authors trace back the literature on BEF theory to a few seminal papers and give a short overview of the export of BEF ideology, starting with the signing of the Convention of Biological Diversity (CBD) in 1992. Whereas the political agenda of the CBD had clear goals and media coverage was strong during the Rio Conference, further awareness of biodiversity topics seemed to coincide rather with the occurrence of ecological disasters (with public reception having a negative relation to distance and a positive relation to magnitude or scale of the disaster) than with an intentional transfer of knowledge from scientists to policy makers and the general public. The low share (23%) of ecosystem-managers that regularly cite scientific literature in their management plans also raises the question whether there has been enough effort up to date to transport the consenus view out of the BEF community. The authors conclude that as long as the scientific findings are not incorporated into policy making, public interaction with the topic will not be directed but rather accidental, happening mostly during discussions of global change phenomena in general. One of the main problems is that communication between scientists, policy makers, and managers is often dysfunctional. The installation of a working science-policy interface is necessary to ensure that scientific consultation of managers and policy-makers can happen. An important step into this direction was very recently taken with the implementation of the *Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)*, an UN initiative that is "recognized by both the scientific and policy communities to address the existing gaps and strengthen the science-policy interface on biodiversity and ecosystem services." (IPBES and UNEP, 2012).

The authors mention that the speed of implementation of scientific findings relies on the public knowledge of, or exposure to the topic (Naeem et al., 2009), but they do not elaborate on ways of how to build up such a basis for action.

Chapter 4 treats the importance of functional diversity for the BEF methodology. Measuring functional trait diversity in species pools of different ecosystems is crucial, because compensation for the loss of a species (and consequently the loss of its functional role in the system) is dependent on the remaining traits in the species pool. There is an ongoing debate over which measurement tool provides the best results, because it is a major problem how to assign species to different functional groups (therefore the exclusion of the use of functional group richness). The authors come to the conclusion that measuring the effect of number of traits on the relative importance of species richness and composition is superior to competing methodologies. The challenge of choosing the right set of traits remains. It is important to note that there is a vital discussion going on in the scientific communities concerning this issue, because designing indicators to show and predict the effects of species extinction is an important prerequisite for conservation.

Chapter 5 treats the relationship between extinction and provision of ecosystem services. To forecast the decline in ecosystem service provision in a realistic way, it is necessary to focus experiments on realistic extinction orders. In the reorganization (structural and functional) of ecosystems, following a shock, organismal traits play a vital role. First it is necessary to determine the vulnerability of species to become extinct, which is dependent on their response traits, second there will be a re-organization of the community mediated by a mix of response and effect traits, and finally the re-organized community will influence the environment respective to its set of effect traits. Extinctions often have cascading effects, which cause secondary extinctions of closely connected species, but it is challenging to predict those because the interactions in and between food-webs are often highly complex.

The facts, that the link between environmental change and extinction scenarios depends on the scale of the ecosystem in investigation, and that ecosystem processes are often mediated through multiple traits, further complicate the situation.

Though generalizations in this context can only be made with caution, experimental evidence showed that, in comparison to random-loss scenarios, more realistic orders of extinction produced a significantly different, often larger ecosystem response. That means that we are likely to have underestimated the impact of extinction on ecosystem services. Also we should not make the mistake of relying only on a small set of keystone species, because we have not yet unraveled the complexity of food-web structure and the full importance of weak interactions between consumers and resources in food-webs. Weak interactions can increase stability of food-webs, when high levels of diversity are present (McCann, 2000).

In chapter 6 the authors work on the theoretical assumption that biodiversity is maintaining stability of ecosystem functioning. This topic was already touched in section 4.1.2, but it needs some further treatment. The theoretical basis for the stabilizing role in ecosystems with multiple stable states is widely accepted in scientific discourses, still presentation of unequivocal evidence for the theory has been rare. First, it is important to define which kind of stability is the focus of the research. Most work is concerned with either temporal stability, resistance to external pressure, or resilience in the face of regime shifts. Second, it was an important step in empirical studies, reviewed in this chapter, to isolate the role of species richness, and to focus on the importance of species composition, which makes the experiments technically difficult, and time-consuming.

In summary the empirical studies reviewed by the authors of chapter 6 show that, if treated in a BEF-framework, biodiversity commonly enhances temporal stability on the community level, meaning stable rates of production and yields of biomass. Evidence for the effect of diversity on resistance and resilience is not consistent. An expansion of the findings presented here to real world systems, for example landscapes, is still difficult, because the experiments were mostly conducted in multiple small scale grassland plots, or microcosms. Therefore extrapolation from these findings to the provisioning of ecosystem services is a complex task and predictions must be made with caution.

Especially the idea of resilience has found a broad reception in different scientific communities although the rare evidence is equivocal. Furthermore food-web traits and dynamics should be included in BEF-studies to make them more applicable to real-world situations. After all it is one of the main conclusions of the authors that species individual identity is more important than species richness per se, which was already mentioned above. Second, the mechanisms behind the processes must be better understood, and third, the effects of real-world diversity changes on the provision of ecosystem services must be observed carefully. Even if there are still a lot of unanswered questions, examples from pollination, and fishery studies manage to bring the theory in line with real world ecosystem services which have major importance for human well-being. It was convincingly shown that higher diversity in these systems correlated with greater stability of service provision.

Further chapters in the book are concerned with the role of microbial biodiversity, and food-web structures, and provide a first step towards the identification of mechanisms. I will now make a jump to the third part of the book, which treats the relationship of ecosystem services and human well-being.

After reaching a certain consensus in the scientific community, translation, and application of scientific findings to design comprehensive management approaches seems reasonable. The problems that scientists and managers face in the real world are topic of chapter 12.

Restoration is a context-dependent and integrative enterprise, but the BEF ideology is not incorporated yet in the decision-making of the biggest part of managers, moreover only a diminishing fraction ($<1\%$) of management decisions are scientifically informed. An issue here is also that BEF-theory has not yet been able to produce robust tools of prediction. Still the integration of BEF-theory and restoration (science) can prove to be a promising route of direct and fast application of scientific findings. The resulting field-experiments of course need to be monitored, which up to date is rarely the case.

The authors conclude that ecosystem services must be tagged with (economic) value to be included into management decisions, because not all of the stakeholders involved in these processes may understand, or believe in the science in the background. Also it is very hard to calculate budgets if the outcomes of the actions are based on uncertain, vague predictions.

In chapter 13 the authors apply the BEF-framework to landscapes modified through human use, especially agricultural landscapes. Predictions go that the area of irrigated land, and pasture land worldwide will double until 2050, to meet especially the growing demand in meat, which will lead to a loss of 10^9 hectares of wildlands. Transformations in that magnitude will have significant impacts on the conservation and management of pristine and agricultural biodiversity. Holistic management, i.e. combining findings from the natural and the social sciences to inform decision makers, is therefore of great importance. Though intensification of agricultural practice has been shown to be a strong driver for biodiversity loss in these systems, and in adjacent wildlands (phatogen transfer, gene flow, agrochemicals), the role of biodiversity on a landscape level is hard to analyze in a controlled experimental setting. This would presuppose that all ecosystem functions in the ecosystem under investigation are known , which is rarely the case.

Following a meta-analysis the authors conclude that complex agroecosystems have higher levels of biodiversity than intensively managed systems, in the same landscape context. Generally, to mitigate against further loss of biodiversity in agricultural systems, two basic scenarios are imaginable: either agroecosystems are designed in such a way that they maintain levels of biodiversity that ensure the stable provision of ecosystem services, or agricultural landscapes are intensified even further, so more space remains untouched, available for "pristine" nature, between patches of managed systems. Both approaches are too simplistic and are not applicable to real-world situations without further conditions. Especially the high input of non-renewable energy into intensive agricultural systems and the economic constraints of production must be taken into account when dealing with the farmers situation. To manage agroecosystems in a way that they are productive without enivronmentally harmfull inputs, and that they conserve local biodiversity is a complex task that requires comprehensive knowledge of BEF-relationships in these systems.

It is not necessarily the case that monocultures outperform mixtures of plant species in terms of production, transgressive overyielding (i.e. higher performance in mixture than in the highest performing monoculture) was found in three out of four experimental sites across Europe. Biodiversity can actively heighten production in managed systems, while additional benefits of diverse communities are also conserved, e.g. resistance to invasive species or diseases (rice blast diseases was found to be >90% less severe in mixtures than in monocultures of rice). But also here evidence is equivocal and similar questions arise like above, concerning real-world application of experimental findings, mechanistics behind the observed processes, and context-dependency of communities in different ecosystems. Mostly though the goal of management is to maximize functionality, be it to control pests or species invasion, and to ensure multi-functionality. In that respect certain minimum levels of biodiversity are needed, that are above those of monocultures.

Another positive aspect of managing for biodiversity in agricultural systems is the insurance value created. Although evidence for the connection of biodiversity and resilience at the landscape level is limited, it has been shown that diversity can buffer against variance in productivity and it was suggested that redundancy in functionality serves as an insurance against environmental fluctuations over large geographical scales and long time periods, and therefore that diversity is essential on the landscape level. The second aspect of insurance value is the mutifunctionality of diverse agroecosystems, which do not only produce food but also minimize the risk of loosing yields to pests, invaders, etc., provide traditional medicines, and contribute to higher marketing value. Location of these, mostly traditional small-scale, farming systems in heterogenous landscapes (e.g. near forests) can bring additional benefits via positive edge effects (e.g. natural predator control of pests through wild wasps).

Even if the list of benefits derived from diverse agroecosystems is long it is often economically more feasible in the short run to clear forests rigorously and to install highly intensified monocultures, that can only perform through constant input of fossil energy. One important task therefore is to make the empirical findings usable and compelling for the end-users, in that case mostly small scale farmers (in total 65% of the world's area are agricultural land, 10% of which are highly intensified, 15% still consist of low-input farming, 40% consist in mixed forms).

Here the authors demand a better, more detailed valuing structure for ecosystem services derived from diverse systems. They give examples of large numbers (100 billion USD per year) of total avoided costs thanks to natural pest control in croplands. Even if these numbers give estimates for global values of these services, it is necessary to resolve the benefits and management strategies differently on different spatial scales.

Another road of steering management into conserving local diversity is via incentives, a way which has, in general, not been very successful. It was shown that active stewardship of local biodiversity in Austria is not correlated with subsidies, but rather with mentality and awareness.

In lower-income or third world countries it was shown, that agricultural diversity can buffer against, otherwise detrimental, changes in commodity prices on the world market and secure viability of small scale farmers. Incentives must be designed to incorporate social criteria like poverty, which is a main impediment for conservation. The authors conclude that, taken everything together, biodiversity will most likely be conserved due to utilitarian or intrinsic values. They suggest process-oriented research, participation from land-managers and steering policy as essential mechanisms to ensure conservation in the future.

In chapter 14 the role of biodiversity for pollination services is discussed. 75% of crop species need pollinators for proliferation, they supply 35% of global crop production. A sharp decline in pollinator species (especially *Apis mellifera*, or honey bee) has been documented in the last 50 years in the U.S. It shows here that relying on a single species for pollination is a dangerous strategy, even if managed honey bee colonies can outperform natural pollinator communities, which are more diverse. On a global scale, loss of pollinators was calculated to cost 153 billion USD per year.

Chapter 15 consists of the attempt to connect the BEF-framework to health issues, to create an interface that is of high concern to the public. The authors show that moral reasons to conserve biodiversity are stronger than utilitarian ones in European citizens. Therefore a disconnection exists between scientific and political focus on economic valuation, and society's perception. But the public is, to a huge part, concerned with health and one important regulating service of ecosystems is the reduction in transmission risk of diseases, which is positively linked to biodiversity. The value of this ecosystem service would translate into people's willingness to pay for reduction of risk, which is different from valuing in terms of production or output of ecosystems and may be more tangible for the lay person.

Chapter 16 treats the role of biodiversity as a guard against invasion and colonization of exotic species and notes the dangers of global homogenization of community diversity through breakdown of dispersal barriers, which is linked to globalization of trade.

The 17th chapter makes a step away from ecological reasoning and puts the BEF—framework into an economic context. Notions of value can be found throughout the whole book and are specified and expanded in this chapter and in chapter 18.

Conservation of biodiversity or safeguarding of functioning ecosystems is commonly referred to be a public good, which is non-rivalrous (if an increase in one person's consumption does not reduce the consumption of other persons) and non-excludable (a person cannot be prevented from using the good) (Common and Stagl (2005), p. 325-326). Open-access to these resources is a logical consequence here, which is known to be a major cause for over-exploitation of environmental resources. Well-studied examples are: the decline of global fishstocks and an acceleration of their collapse rates in the past 60 years; and the adverse impacts of habitat loss, which is the single greatest cause for biodiversity loss. A major cause for this situation is the lack of markets for these goods, which are mostly treated merely as externalities. An ecosystem externality is defined as an economic activity of an individual, that has an unintended impact on the well-being of others (Common and Stagl (2005), p.327), e.g. through altering the provision of ecosystem services, but were the consequences are ignored by the initiator.

Another economic aspect of biodiversity is so called biodiversity insurance, this is the option value of conservation in the face of environmental change in the future. As noted above a more diverse community will be able to deal with a wider array of possible fluctuations, than a less diverse one. A logical consequence of this is that the secure provision of goods and services, which have an economic value, from an (agro)ecosystem depends on the initial diversity of the system. To ensure a sufficiently high level of biodiversity, in many cases the system has to be actively managed, also to keep a number of different optional pathways open to respond to challenges in the future. In this context an often noted discrepancy arises between the optimal private versus the optimal social solution, a situation where subsidies are often used in trying to ensure a socially optimal allocation.

In some cases markets for biodiversity, or better for goods that are in direct connection to high levels of biodiversity, do already exist. They all have a common feature, which is that they create a revenue which makes conservation feasible. Working examples are: ecotourism and bioprospecting.

Ecotourism currently is one of the fastest growing segments of the tourism industry and is creating revenues in the range of 400 to 500 billion dollars per year. Bioprospecting on the other hand is the screening of a large number of indigenous plant and/or animal species for compounds to use in the development of pharmaceutical products. An estimated share of 25% of drugs sold in developed countries and 75% sold in developing countries, were developed using natural compounds. Controversies with bioprospecting may arise when it comes to the question of IPRs (Intellectual Property Rights) of genetic resources and their trade related aspects (i.e. TRIPS Agreement) and the sharing of benefits between international corporations and indigenous people (see Brand (2011)). It often poses a problem that also here there are misalignments between the optimal private and the optimal social allocation. Therefore governments and NGOs more and more rely on community based conservation efforts paired with either land acquisition, or direct/indirect funding.

In situations where no markets for biodiversity exist governments can use certain economic instruments to create market-like conditions, examples are: *payments for the provision of ecosystem services* (directed mostly towards land-users), a special form of these payments can reward farmers for taking private land out of production; *transferable development rights*, which can be compared to cap and trade schemes for emissions of carbon dioxide and depend on the right choice of the planning agency; and *auction contracts for conservation*, where land-owners bid for conservation contracts given out by the government, which has the advantage of being a transparent system. Altogether these instruments require accurate knowledge of the ecological and the economic circumstances in the area to which they are applied. When using such steering mechanisms the government, or international body must always calculate the social costs versus the benefits, because for example pricing regulations in developing countries may disadvantage the poor, who rely heavily on basic natural provisioning systems. Therefore institutions which apply market-like instruments should be open and flexible and include equity criteria, in addition to ecological and economic criteria, into the analysis of the system at hand.

Transboundary externalities exist in an international dimension with the main problems being: ill-defined property rights in environmental resources and the adverse impact of trade on biodiversity through the specialization of local economies, which in turn leads to large-scale habitat conversion and hence loss of species; and the invasion of foreign species via trade routes. Regulations to mitigate the effects of transboundary externalities are put in place through the CITES (Convention on International Trade in Endangered Species) treaty, in the form of trade prohibitions.

In conclusion we are facing local and international market failure, which is often due to perverse incentives which lead private decsion-makers to destroy, or at least not protect biodiversity. It is therefore vital to design direct incentives, put in place institutions that regulate access to environmental resources and try out new financial mechanisms (see above) to protect reservoirs of diversity from over-exploitation.

The question still remains why monetary valuation is thought to be of such an importance when it comes to biodversity conservation and ecosystem services. What is the underlying cause for putting a 'price tag' on complex ecosystem functions even if calculations are mostly "guess-timates"?

In chapter 18 the authors argue in favor of the valuation of ecosystem services in economic terms. Herein the economic valuation serves as a tool to reveal people's preferences. They object that value is an inherent property of an asset, but state that it is generated by the preferences of many individuals acting independently and in concert. They refer to standard utility-based economic theory and it's applicability in the context of biodiversity. An environmental service therefore has the attributes of being instrumental, anthropocentric, subjective, context- and state-dependent and marginal. What counts ultimately is society's willingness to pay for the services provided, this in turn depends on the magnitude of the opportunity costs individual actors face. Opportunity costs means that for obtaining the ecosystem service, which is thought to be scarce in supply, people have to give up something else, they could have purchased for the money. Now if markets do not reveal society's preferences to invest in ecosystem services, then other mechanisms must be used to express the social value of the services, because else over-exploitation and degradation take place. So the main problem is that for most of the ecosystem services, especially regulating and cultural services, no markets exist, which makes them essentially invisible to the economy.

The approach used here to capture the full value of ecosystem services is called the *total economic value* (TEV), which can be split up into different forms of value that the ecosystem provides us with. The main distinctions are between *use value*, which benefits the individual and *non-use value*, which benefits others. And secondly between *direct use value*, which encompasses provision of 1. consumption inputs, such as food, 2. production inputs, such as industrial resources, and 3. non-consumptive inputs, such as recreation; and *indirect use value*, which includes mainly regulating functions of ecosystem services, like soil fertility, climate regulation, or pest control. Biodiversity can also have *option value*, meaning that it includes components (mostly genetic potential) that will come to use in the future.

Direct use, indirect use, and option value can either benefit the individual or the community as a whole. A qualitatively different set of use forms are: *vicarious use value, bequest value, and existence value*. These attributes of ecosystems exclusively have *non-use value*, because they are related to people's willingness to pay for the conservation of biodiversity for the benefit of other members of the public and/or future generations, as well as for the mere existence of biodiversity without respect to present or potential usage.

In the following the authors provide an overview on the different valuation methods for ecosystem services. A short list plus description of the different methods will be provided in my review of "The Economics of Ecosystems and Biodiversity : Ecological and Economic Foundations" (TEEB) (Kumar, 2010) (see section 5.1).

In concluding chapter 18 the authors re-state that ecosystems are "important but often poorly understood components of wealth[...]" (Naeem et al. (2009) p. 261). Economic valuation is vital to monitor and protect the sustainable provision of ecosystem services. Throughout the chapter they repeatedly mention the lack of a firm basis of ecological knowledge, from which it would be possible to infer exactly the right valuation methodology. I argue, that it is not necessary to obtain ecological knowledge of the problem, that has a law-like axiomatic quality, because people have always and very successfully used heuristics in science (see Wimsatt (2007)). Also the authors fail to note the difficulties in identifying and measuring preferences, as well as the questionableness of the results of economic valuation studies based on such individual preferences. I will also treat this criticism more thoroughly in sections 6.2 and 6.4.

Naeem et al. (2009) provide a synthesis in the last part of the book. A short summary of chapter 21 will serve to wrap up with this informative, useful and not to forget highly contemporary piece of work.

The chapter turns around the question whether the effects, that global change has on biodiversity and ecosystem functioning, are predictable. Prediction is a central part of modern scientific activity and even if the BEF idea is established in the ecological, and to parts in the economic community the applicability of the theories and their power in raising public awareness and making practical management suggestions, lies to some part in the skill of the science to extrapolate real-world phenomena. This of course would be much easier if the mechanisms that connect biodiversity to ecosystem function and ultimately to human well-being would be known. Future studies will be concerned with this question and, because of the fact that the number of studies in that particular field of interest has risen significantly in recent times, hope for influential discoveries is not illusory. The two main challenges will be to make the research more realistic and also real-world applicable, and to engage the public to contribute to the task of conserving biodiversity. To accomplish these goals the authors pledge for a unified methodology composed of natural and social sciences and for finding ways of how to communicate the complex message of the BEF-framework to the non-scientific community.

In summary: "The main message from this volume [...] is that biodiversity conservation is an essential element in any strategy for sustainable development." (Naeem et al. (2009) p. 295).

We have now very thoroughly reviewed the book from Naeem et al. This was necessary because the book covers the central scientific findings concerning biodiversity and ecosystem functioning, first of all from a natural science standpoint, and consequently reaches out into the societal sphere. With the treatment of economic dimensions of the problem of biodiversity loss the authors tried to make the important bridge between theory from natural science to real-world applications. This will be further elaborated in the next section.

5 Background - Economics

5.1 Review of TEEB

The TEEB ('The Economics of Ecosystems and Biodiversity') study has its beginning in a meeting of the environmental ministers of the G8 + 5 countries, 2007 in Potsdam. It was inspired by the Stern Review on the economic impacts of climate change and its main objective is "to assess the economic impact of the global loss of biodiversity in order to present a convincing economic case for conservation." (Kumar (2010) preface, p. xvii).

In contrast to climate change, biodiversity loss is not easily measurable with the help of a single indicator, like measuring emission of GHGs (greenhouse gases) in CO_2 equivalents. The linkages between biodiversity, ecosystem functioning, and human well-being consist of a multitude of interrelated parts, they exist on and across very different scales (from genes to ecosystems), and the mechanisms behind the processes remain largely unknown. All of these facts make it a complex endeavor to express ecological assets in monetary terms. In addition, ethical questions can be raised about the legitimacy of putting a price on nature per se. Nevertheless the authors of the TEEB plead for economic valuation, because it serves as an important feedback mechanism for a nature-distant society, and because it is an universal form of communicating importance in a market-centered world.

The authors uncover the root of the problem in "the *nature* of the human relationship with nature, and in our dominant economic model." (Kumar (2010) preface, p. xviii). They recognize the apparent shortcomings of neoclassical free market capitalism when it comes to dealing with common goods provided by nature. They also state that: "Placing blind faith in the ability of markets to optimize social welfare, by privatizing the ecological commons and letting markets discover prices for them, is not at all what TEEB is about" (Kumar (2010) preface, p. xxiv). Following the fact that 'you cannot manage what you do not measure', the concept of the TEEB is to design a very detailed, yet context-sensitive, methodology of valuation. They rely on pragmatism and real-world applicability rather than on revolutionary change of the economic and societal system. Although the authors see that such a change is necessary to achieve a sustainable society, they believe that small, workable steps are the right mean to get there. A certain contradiction arises, because the topic of alternative economic systems remains untouched throughout the book. The question, whether or not it is possible to implement the TEEB methodology in the current economic environment and thereby initiate incremental change of the system as a whole, remains somewhat unanswered. This may be due to the relatively short history of this project.

Let's take a look into the book and highlight some of the central points of this seminal work. We have already covered Chapter 2, about the ecological basics, above. Here I will focus on the TEEB methodology of valuation (Chapter 5) and the socio-cultural context of valuation (Chapter 4).

Chapter 5, named *The Economics of Valuing Ecosystem Services and Biodiversity*, comprises the TEEB methodology of valuation. In a technical sense, the value of a good is an information for society about the relative level of scarcity of the good in question. It depends on the willingness of people to trade off some of their private wealth in order to conserve, in our case, the natural resource or ecosystem service. We have seen above that it will ultimately depend on the magnitude of the opportunity costs, whether people will actually pay for a certain ecosystem good or service. This is a classical utilitarian and marginalist approach to valuation. Also valuation is the first step in the creation of markets where goods and services can be traded. The TEEB approach to valuation is mainly based on people's preferences in contrary to production or maintenance costs. It encompasses three consecutive stages: First, values must be *demonstrated* empirically; Second, values must be *appropriated*, that means they must be internalized in an existing value system, what makes it possible to create incentives; Third, the benefits that arise from conserving and trading the goods and services must be shared in a fair manner, between individuals, communities, firms and states.

We have already mentioned the TEV approach above, I will now coarsely explain some of the valuation methods used in that framework. There are three possible schemes to measure the value of an ecosystem good or service:

1. *Direct market value*: Direct market value can either be solely based on market prices, where markets exist; or can be cost-based, calculating the costs for avoiding, mitigating or replacing the loss of the service or good in question; or it can be production function-based, calculating the surplus value contributed through a functioning ecosystem.

2. *Revealed preferences*: Where markets exist people's preferences to conserve functioning ecosystems can be revealed through, either the 'travel

cost' method, calculating the willingness to pay or sacrifice time for the enjoyment of a natural recreation site; or the 'hedonic pricing' approach, calculating the implicit demand for natural attributes of marketed commodities, such as the landscape around a housing property.

3. *Stated preferences*: Where no markets exist, it is necessary to simulate a market to uncover people's willingness to pay in the face of a hypothetical imposed change of the provision of goods and services. The methods here are contingent valuation (how much would one pay), choice modelling (how would one choose between alternatives) and group valuation (stated preferences plus a deliberation process).

All of these different approaches also have inherent advantages, limitations and biases.

Direct market valuation techniques can only be used when market data are available. In some cases though, markets may be distorted, because of subsidies or imperfect competition. Production function-based valuation is often impossible because of the lacking understanding of the processes that connect biodiversity, ecosystem functioning and service provision.

Revealed preferences methods also rely on functioning markets, they do not capture non-use values, and they infer value of the environmental good from the value of a marketed good, which may not be perfectly adequate.

Stated preferences methods are often the only way to measure non-use values, but the explanatory power of the results is reduced because of the discrepancies between people's behavior in designed situations and the real world. Even if the questionnaire is perfect, different states of knowledge about the topic may lead to conflicting answers. There is a lot of complex psychology involved in these testing situations and many people may actually not be willing to put a price or number on bequest or spiritual values.

For more detailed information on the different valuation techniques and their limitations see Kumar (2010), p. 196-205.

An important constant in every valuation study is uncertainty, it stems from the nature of the ecosystem service, the application of the valuation tools, and the way how people form their preferences. This preference uncertainty goes down as the knowledge or experience with the service rises.

Another aspect of uncertainty is it's changing magnitude when the system in question is near a tipping point or regime shift (see Schellnhuber (2009)). In this situations where the resilience of the system is very low (Gunderson and Holling (2002) p.40ff.), uncertainty becomes an obstacle that makes standard valuation methods nearly impossible. This calls for a set of minimum standards and the implementation of a precautionary principle by policy makers, and a dynamic valuation toolkit. Further challenges for valuing ecosystem services encompass the shortcomings of a marginalist approach of valuation in the face of possible regime shifts, the complexity of detecting thresholds of that shifts, the failure of society to value species before they disappear, the limitations of science to predict ecosystem dynamics, and the problem of future uncertainty.

Some of these problems can be tackled when a wide range of stakeholders are included in the process. Their voices must be weighted, respectively to their proximity to the ecosystem that provides. This context-sensitive approach can lessen social conflict and enrich the valuation process with local knowledge.

Another approach to deal with the apparent lack of information is the so-called *benefit transfer*. It means to transfer findings from similar studies to different locations, which is comparably cheap and fast, but has many drawbacks because of the complexity of ecosystems. The same holds true for scaling up values from geographically smaller ecosystem to biomes.

In conclusion we see that valuation of ecosystem services is neither easy nor straightforward. Still "the approximate contribution of ecosystems to the economy remains urgently needed" (Kumar (2010) p. 242) to trigger politcal and societal will to conserve these vital assets. To get there, multi-criteria methods and deliberative processes will be needed, as much as a better collaboration between economists and ecologists.

The authors of the TEEB study very well understand that economic valuation of ecosystem services is not an easy task. In addition to the ecological and the economic dimension, sociological and cultural aspects must be included into the process to structure it according to the requirements of sustainable development.

Chapter 4 of the book is the attempt to do so by: mentioning some socio-cultural theories that try to describe the relationship of humans, individuals and social groups, with nature; touching the topic of trade-offs in valuation; and finally describing the challenges of valuation. A short overview will now be provided.

The first part of the chapter serves to uncover cultural differences in the way people perceive and treat nature. The western perspective, following it's roots in a Judaeo-Christian belief-system, sees nature as a system serving mankind, that needs to be controlled. This utilitarian view is complemented by a long history of divide between the social and the natural (biological) sciences. It stands in contrast to more holistic concepts of the human-nature relationship which can often be found in indigenous systems of belief, which include for example pantheism and animism. Conservation has to deal with both of these aspects, but international or global programs will likely be much more influenced by the western perspective, which is widespread and dominant in our current geopolitical system.

The individualistic philosophy of economic rationality has nowadays largely replaced the philosophy of naturalism, which explains human-nature relationships according to natural (physical and biological) laws. This has led the focus of conservation to shift from the protection of pristine, untouched habitats, as an moral imperative, to the acknowledgment that conservation is a social choice, with different groups holding different interest on what to protect and why to do so. Taking the variety of social actors into account is an important step, but the utilitarian approach does also bear major problems. For one it is not really possible to deduce social welfare from an individualistic basis, and for two there are certain limitations to a purely liberal view of the world (see Sen's 'Liberal Paradox', reference in Kumar (2010)). An important implication from this discussion for the TEEB study was noted by the authors of chapter 4 as follows: "[...] economics values [...] are socially and culturally constructed, as are concepts such as ecosystems and biodiversity." (Kumar (2010), p. 155).

Various previous studies and international agreements, like the CBD (Convention on Biological Diversity), the MEA (Millenium Ecosystem Assessment) and the EPA (United States Environmental Protection Agency) strategy, have proposed a shift away from simply protecting species to protecting ecosystems and biomes and support a view of the environment as internalized in political and economic reality. This approaches call for a valuation methodology that goes beyond economic tools and includes social and cultural criteria via capturing preferences of different interest-groups in different contexts. Such a multi-criteria approach is not easily conducted and has limitations (see above). One challenge for the TEEB study is to find a middle ground, that takes into account these limitations and that helps to shift the current mainstream political strategy, that is still based on "protecting and isolating ecosystems from economic development and commodity markets, [rather] than on redefining and regulating the latter." (Kumar (2010), p. 155). A valuation exercise therefore becomes a relative, rather than absolute venture, because the main objective lies on the "questions of when, how and what to value, and whose values count." (Kumar (2010), p. 157).

Following this argumentation multiple trade-offs arise during the valuation of ecosystems and services they provide. One such trade-off is related to the dangers of creating a 'commodity fiction' when valuating ecosystems in economic terms, thereby creating the belief that goods and services can be owned and traded in markets for money, which makes them substitutable. Furthermore it is problematic to assumes strict rationality in the process of forming preferences (see section 6.4). There are institutional, cultural and ethical constraints on imposing a commodity system on indigenous communities and trying to make them active stewards of local biodiversity. Finally bioprospecting programs can be questioned on the ground that nature then cannot be considered a 'common heritage' anymore. On questions about rightful ownership and intellectual property of nature and fair allocation of profits between international cooperations, nation states and local communities see also Brand (2011).

In the following paragraphs the authors discuss different models of human behavior, which is also part of this work (see section 6.4) , and call for the use of deliberative and multi-criteria methods as 'value-articulating institutions'. The inclusion of deliberative methods in the context of environmental decision-making has the potential to open spheres of discussion to a wide range of stakeholders and forming preferences, rather than just recording them, with the aim being some sort of informed consent (see also section 6.6). This methodology though holds the dangers of being used in a superficial way, simply to complement traditional methods, and may critically underestimate the role of power and leadership in decision frameworks.

In contrast to the potential negative implications following valuation methods in a standard economic framework explained so far, the authors find clear advantages in the ability of valuation to serve as a feedback mechanism for society and assistance in decision making. Expressing the importance of biodiversity and ecosystem functioning in terms of utility and money can help to change people's attitudes towards nature and create more environmentally friendly institutions. It is also important to consider the emotional dimension and different feelings towards nature in the course of valuation.

Challenges involved in valuation methods are topic of the last part of chapter 4. The first challenge comprises the fact of inequality around the world in terms of wealth. High levels of diversity are often found in places of low socio-economic development. Local people may not always recognize incentives to preserve biodiversity when they can attain economic profit otherwise. Valuation and conservation therefore must take into account the differences in distribution of wealth and equity issues of development, and strive for fair redistribution of profits obtained (e.g. from bioprospecting or ecotourism), and pollution caused (e.g. emissions of GHGs). This becomes even more important as the place of production and the place of consumption of many ecosystem goods are geographically far apart, what indirectly supports intensification and exploitation, by making people unaware of the consequences of their consumption patterns.

Another challenge is the complexity involved in choosing the right scale of application and socio-economic context for a valuation attempt. Tension may arise between stakeholders and biological processes across different spatial and temporal levels. Scientists and planners must take them into account accordingly, to address the need to promote conservation outside of protected areas.

The third and final challenge is which valuation methodology to choose to fruitfully guide decision-making. The authors favor methodologies that fulfill the requirements of Ashby's 'Law of Requisite Variety', which states that "any regulatory system needs as much variety in the actions it can take as exists in the system it is regulating." (Kumar (2010), p. 172). Such a valuation scheme must include the variety of preference forming heuristics that people use when making a decision and it goes beyond the aggregation of individual values, to a pluralistic approach. If it is assumed that the valuation method is ultimately a value-articulating institution (see above), then the choice of the method and the methodological framework does also influence the outcome and subsequent behavior.

In conclusion the authors re-emphasize the importance of valuation as a feedback tool fostering awareness, but they also admit that "valuation mechanisms should be seen as part of a broader range of diagnostic and assessment tools and political-institutional mechanisms that facilitate the understanding of complex socio-ecological systems." (Kumar (2010), p. 175). Valuation in the author's eyes "is essentially a matter of choosing how to perceive the human being itself, how to perceive human's place in nature, and how to perceive nature itself." (ibid., p. 175). Therefore It has a strong normative side that must not be forgotten when we try to put a value on environmental features, which will not be accomplished by relying on 'one size fits all' approaches.

5.2 An historical outline of economic value theory

The notion of value is central to economic reasoning. This short, chronological sketch of the different historical approaches to a theory of value should serve to get behind this term that is often used in this text and therefore should be elaborated at least a little bit. It is based on the work of Screpanti and Zamagni (2010).

Already in 16th century Bernardo Davanzati tried to explain the value of a good in the sense of it's proportional utility and rarity, i.e. dependent on the overall available quantity of the good. In the 17th century Geminiano Montanari took up that idea and explicitly made the "desire of men" (Screpanti and Zamagni (2010) p. 42) the main determinant for measuring value. The utility of a good eventually depends on it's ability to meet a certain need or want of the consumer. The mercantilists of that time believed that the natural value of a commodity was given through the market price, which in turn was determined by the forces of supply and demand. The price in turn was said to be determined by the use value, or utility, of the commodity in question.

In the beginning of the second half of the 17th century William Petty, one of the forerunners of political economy, made a contribution to the theory of value which was innovative, insofar as he dismissed the subjective theory of value altogether. He tried to establish the term 'natural value' which he connected to the costs of production of a commodity. Although he could not come up with a clear mechanism he anticipated with his thoughts a labor theory of value, which can be found again in Marxian theory. He also concluded that the contribution of land to the generation of value was diminishing in comparison to the contribution of labor and therefore excluded the value of land from his unit of measurement.

In the late 17th century Ferdinando Galiani built on the work of Davanzati and Montanari to push the theory of utility value even further. He argued that value is not an intrinsic property of a good but that it arises from the consumer's choice. Additionally he claimed that one has to start from the individual to determine the value of goods. In that respect, he or she will ultimately decide whether the purchase of a certain good compared to another one is superior in value. Or as in Galiani's own words: "value is and idea of proportion between the possession of one thing and that of another in the mind of a man." (Screpanti and Zamagni (2010) p. 60). Obviously Galiani's conclusions read familiar with contemporary classical and neo-classical economic theory.

The next step leads us to Adam Smith, who in the late 18th century made an important contribution, which in essence states that "Labour, [...], is the real measure of the exchangeable value of all commodities." (Screpanti and Zamagni (2010) p. 70). Vice versa only goods produced through human labor have a value. But he also saw that in a capitalist society the calculation of a price on the sole basis of embodied labor was problematic, because the price must be sufficiently high so as to include a profit and a rent, besides the worker's payment. Therefore the 'labor commanded', which is the amount of labor which can be bought in return for the commodity that was produced in the first place, will always be greater than the amount of embodied labor in the commodity.

In the end of the 19th century during the so-called 'Marginalist Revolution' economists, like William Stanely Jevons, Carl Menger and Léon Walras overcame the classical economic theory, including Marx, and a neoclassical theoretical system was established in the western world. Although expanded, discussed and critiqued in many ways the neoclassical system prevails until today and therefore the main characteristics should be discussed here.

The central advancement of the 'Marignalist Revolution' consisted in the new interest for "the problem of allocation of given resources among alternative uses" (Screpanti and Zamagni (2010) p. 165). A quote by Lionel Robbins subsumes the whole of economic science under this precondition: "Scarcity of means to satisfy ends of varying importance is an almost ubiquitous condition of human behavior." (ibid p. 165). Later that line of thought culminated in P. A. Samuelson's statement that "there is a simple principle at the heart of all economic problems: a mathematical function to maximize under constraints." (ibid p. 166). Neoclassical theory accepted the philosophical stance of Utilitarianism and reformulated it in a way, that "human behaviour is exclusively reducible to rational calculation aimed at the maximization of [marginal] utility" (ibid p. 166). Further: the 'substitution principle' was introduced, which claimed the full substitutability of one good for another; the theory made the individual the main factor in the economic process; the laws of economics were seen on a par with the laws of physics, i.e. having the characteristics of absolute and objective natural laws, and leaving no room for social relations; and finally a subjective theory of value was adopted, meaning that value of a good can only be existent if an individual actor chooses to desire, want or need, that specific good.

It should also be mentioned that in the course of the 'Marginalist Revolution' the paradox of value (or Diamond-Water paradox), which had bothered scientist since Galileo Galilei up to A. Smith, was solved. In short the paradox goes like this: Why is the market-value of water low when compared to diamonds, even if water is necessary for survival and diamonds have no apparent practical use? In a famous passage of his *Wealth of Nations* A. Smith tried to tackle the problem with his distinction between "use value" and "exchange value" of a good, which he thought to be two independent variables. Thereby he did not manage to solve the paradox and lead some of his successors, especially Marx and Ricardo, to the conclusion that only a labor theory of value was adequate. Altough even Galileo described the paradox and proposed a solution based on the relative scarcity of gold or diamonds in proportion to arable land or water, it was not before the theory of marginal utility that the paradox was solved. The solution in short goes like this: Because of the overall large quantities of water available, when the thirst is quenched, an additional unit of water will not have a high value and people's willingness to pay for that unit will be low. In contrast the overall supply of diamonds is small and an additional unit of diamond will have a great value, therefore people are willing to pay a high price for it. So even if the total utility of water to mankind is much greater than the one of diamonds, diamonds will always score a higher market price than water as long as the two commodities are so different in supply. The marginal value of diamonds is much greater than that of water. (Screpanti and Zamagni (2010), p. 84).

Subsuming this short stretch of value theory in economics it seems reasonable to highlight the different approaches that can be found throughout history. We can see that the scholars focused on very different conceptions of how a good is attributed with value and just how hard it is to come up with a practical and realistic one. In essence the starting point for the inquiry into the meaning of value is, that value lies on a scale between objective and subjective properties of a good, and that value was either claimed to be an intrinsic or extrinsic property. After the labor theory of value was largely dismissed by the scientific economic community, the utilitarian perspective is still valid and widely acknowledged today. It is important to keep the development of the scientific discourse, circling around the notion of value, in mind when approaching the problem of valuating environmental assets like biodiversity. It is obvious that economic scholars throughout history have not considered the natural input of ecosystems a great part of the value of a commodity. The water-diamond paradox gives a hint on to why this is the case. It may well be that this lack of interest in the past has led to some of the difficulties that now arise when people are trying to calculate values for biodiversity and ecosystems. Biodiversity is not indefinitely abundant and often does not go down gradually but suddenly with ongoing exploitation. Ecosystems and biodiversity are common goods, which do not necessarily fall into categories of individual 'needs' and 'wants'. Both of these characteristics makes valuation in the neoclassical framework difficult. Also it is very important to understand which underlying theoretical system is used in current publications about the topic.

In the next part of this thesis I will go even further into the complexity of protecting our biodiversity heritage.

6 The complexity of managing biodiversity and ecosystems

Compiling the most recent evidence on the problem of biodiversity loss was the first step in my research. I have provided an overview on the ecological importance of conservation and I showed that conservation is a vital element of sustainable development. It can be said that conserving what remains of the biodiversity on this planet is vital for human well-being. The means to achieve the protection of species differ between authors, with regard to profession and believe.

We have seen that there still is a lot of uncertainty involved in the ecological background of the whole story. This uncertainty and the complexity involved in ecological processes are obstacles to economic valuation and political and societal decision-making. Communicating scientific results to politicians is complicated and awareness in the public is said to be low (see references above). Management approaches must take these constrains into consideration to be effective.

The purpose of this part is to highlight those approaches that, taken together, provide the best tools to manage biodiversity and ecosystems in a holistic sense. It also includes difficulties, which will most likely be encountered during the process.

6.1 Management options - overview

Hooper et al. (2005) come to the conclusion that managing biodiversity to ensure the longterm provisioning of ecosystem services is an established goal of many conservation efforts in practice. These processes are mostly expert driven and rely on intergovernmental panels and large scale conservation initiatives. On the other hand this philosophy has not yet found broad recognition in the commercial agricultural sector, here management is mainly production or output oriented and focuses on short term gain rather than long term stability and reliability. Here, the main causes are economic constrains and competition on the market. Of course there are also biodiversity sensitive management examples like home gardens or publicly managed forests. A centrally important point of biodiversity conservation is the need to maintain even higher levels of diversity with increasing spatial and temporal scales. Therefore the authors ask for more scientifically informed adaptive management and more efforts of conserving species to make sure that the foundation for future management approaches, which will hopefully be based on even more sound scientific knowledge, is not undermined. Taking the necessity to act into account ecologists face the challenge to communicate their findings to the decision makers in charge.

Other authors emphasize the need to confront a much broader audience, than just the decision makers, with the process of reinforcing biodiversity conservation. Novacek (2008) argues in favor of efforts that would increase the public awareness of biodiversity issues. A central feature of this quest is the improvement of educational channels, like museums, zoos or the media to reach out, inform and create a much wider reception of the problems at hand. Also bringing together lay people with scientists, fostering a reconnection to nature, and strengthening the willingness to incorporate environmental considerations into the choice of public representatives through voting, can help acknowledging the pressing problem of biodiversity loss. See also Lindemann-Matthies and Bose (2008).

The third widely distributed approach is placing economic (monetary) value on biodiversity, to allow for the creation of markets and trading of ecosystem goods and services. It was stated by Jones-Walters and Mulder (2009) that "the failure of society to place a value on nature has resulted in the degradation of ecosystems, [...]". The TEEB treats the problem of valuation and putting prices on ecosystems in a very comprehensive way (Kumar, 2010). An alternative approach was proposed by Schellnhuber (2009), who suggests the deliberate creation of tipping points in socio-economic systems, to flip these systems into a sustainable state.

All of the three approaches have different strengths and weaknesses and none of them is totally bias-free. Still they are worth mentioning as biodiversity issues encompass a wide variety of interrelated problems, which call for multiple routes to solutions. The three areas of management above coincide with the three dimensions of biodiversity evaluation: the ecological or functional dimension, the moral and aesthetic dimension, and the economic dimension (Novacek, 2008). Management then can take economic, scientific or political forms or, as most of the time, a mix between the three. How students rank biodiversity issues in accordance to these dimensions and whether their answers root in differences in educational background and what the implications for sustainable development are, will be a focus of my research, but before I come to the empirical part I will dive a little deeper in the difficulties of managing and conserving biodiversity and ecosystems.

6.2 Differences and similarities of biology and economics and consequences for valuation of ecosystems

Great hopes are now laid on the economic valuation of ecosystems. It seems that there is a strong need to classify benefits, derived from intact environments, in monetary terms. Clear numbers would serve decision makers and the public well in understanding what is at stake, even if they only posses limited knowledge on why the stakes are high. Still this is a controversial matter, because there must be a moral or normative justification to put a price on nature per se.

In this section I will put together voices and suggestions from different scholars. I will try to find out what they consider the root of the problem and what they provide as possible pathways to a solution.

With the goal to establish a panel on biodiversity, comparable to the IPCC (Intergovernmental Panel on Climate Change), the international community seemed to have realized the need for acting on biodiversity-loss only very recently. The rather sudden focus on this particular problem may have been fostered in the growing awareness of climate change. Nevertheless, apart from NGOs which have been involved in conservation issues for the whole time of their being, scientists from the discipline of Ecological Economics have already dealt with the topic almost twenty years ago.

Together with Carl N. McDaniel John M. Gowdy has written on the tensions between biological and economic systems with a lot of insight (Gowdy and McDaniel, 1995). He comes to the important conclusion that the self-organizing principles of markets do not at all coincide with the self-organizing principles of ecosystems. Market economy has evolved in the course of mankind's cultural evolution, approximately during the last 10 000 years, whereas natural evolution happend in the last 3.5 billion years. Also, according to Gowdy & McDaniel, biodiversity loss is the global change phenomenon most threatening long term survival of humans, because it is the most irreversible one. In comparison to climate change, fossil records indicate that natural recovery from mass extinction events takes tens to hundreds of million years.

Michael J. Novacek & Elsa E. Cleland reason in a similar direction in their paper (Novacek and Cleland, 2001). They hope for a scenario of recovery that "involves enlightened human intervention beyond simple measures of wilderness preservation" (Novacek and Cleland (2001), p. 5466). They also acknowledge that recovery from mass extinction events in earth history has taken a very long time span (millions to tens of millions of years), but they question the applicability of such data to the current crisis, because of the strong effect human action, through mitigation and management, may or may not have on ecosystem recovery.

Gowdy & McDaniel state in the following that pure economic treatment of ecosystems is bound to fail, because of the differences in the duration of processes in ecosystems versus the time it takes to make an economic decision. They continue with the claim that it is impossible to assign a "correct" price to an environmental good or service. It is not enough for sustainable development to calculate approximate prices that reflect the underlying environmental inputs to a good or service, because in an economic framework that consists of many individual decisions, only perfect information would assure perfect allocation of a given resource, and this is why a neoclassical framework must fail in protecing biodiversity. To solve this unfortunate situation Gowdy & McDaniel rely on political intervention that will on one hand expand wildlife areas which are essentially untouched by economic activity, and on the other hand use the remaining area of productive land more efficiently and sustainable. They recognize that these policies must take the uncertainty of environmental processes and real-world human behavior into account to be effective.

Gowdy's & McDaniel's solution consists of a mix between renewal of current economic reasoning and political action. They see clear limitations in simply valuating ecosystems. Novacek & Cleland argue for much more scientific effort from the disciplines of ecology and especially of biological systematics, to better inform management decisions. Although they recognize that scientific data alone are not sufficient to ensure conservation, they do not mention economics or policy as part of the problem nor the solution.

It is interesting to spend some more time on the work of John M. Gowdy, especially on two papers he published in 1997. There he writes about the connections, similarities and dissimilarities of biology and economics. Although the articles have an essay-like character, they contain a lot of important insights, to why Gowdy thinks, that with our current economic system we will never be able to successfully tackle environmental problems like biodiversity loss. Even complete and exact valuation of ecosystem assets alone will not suffice to solve these issues of high complexity and interconnectivity between natural and human spheres.

Gowdy (1997a) begins with a journey into the history of both scientific disciplines. He explains the connections between the theoretical frameworks, one could also say systems of belief, of Charles Darwin, philosopher Herbert Spencer and economist Alfred Marshall, in the late 19th century.

Marshall who was an important contributor to neoclassical economics and the marginalist revolution in England at his time, incorporated Darwin's and Spencer's ideas of evolution and natural selection in his work. He directly adopted the idea, that evolution is progressing in small steps, creating only marginal change, and applied that thought on the mechanism of social institutions, which he thought to be doomed when changed too fast. He also believed in the importance of competition in a functioning market, but did not totally agree with the notion of 'survival of the fittest' and the social Darwinists of that time. He proposed an evolutionary philosophy in which the whole society would benefit (Screpanti and Zamagni, 2010). It was probably also due to his education in Christian moral philosophy that he was in favor of state intervention in the economy to alleviated poverty. Even if Marshall had not fully agreed with the social consequences of Darwinism, as he understood it, he was one of the first to incorporate this idea into his economic reasoning. His interest in natural science seems clear, as he also studied physics in Cambridge.

Gowdy sees in the parallels between Marshall, Spencer and Darwin the two main ideas that described evolutionary theory throughout the 20th century: progress through competition and gradual change (Gowdy (1997a), p. 377). He claims that these ideas are still widely dominant in economic theory today, although the Spencerian view, that competition is a necessary prerequisite for evolutionary and social progress, does not hold in contemporary biology nor sociology anymore.

Gowdy criticizes the misuse of evolutionary concepts by neoclassical economists like Milton Friedman and others, who use them to explain and defend competitive markets and capitalism in general. Of course there are also other scholars, like Georgescu-Roegen, which have surpassed this narrow view. Gowdy himself can be put into this category. He is in favor of a new kind of economics in the context of economy-environment conflicts, which he calls 'structural economics' and which "promises to free economics from the straightjacket of marginal analysis" (Gowdy (1997a), p. 379). In contrast to the conventional view that every economic actor must inevitably strive for maximization of profits to survive natural selection, structural economics focuses on non-optimal economic outcomes, which can often be observed when environmental and social resources are exploited. The mechanistic and deterministic view of the predominant economic theory often does not coincide with what is going on in the real world, may it be in social or in ecological systems.

The main argument of this paper is that economics must change fundamentally to deal with environmental problems. It seems that Gowdy is not willing to accept only little alterations of the existing paradigm, because the understanding of natural and evolutionary processes in economics is flawed. As long as this mindset is not changed, no economic instrument will ultimately work with instruments of conservation in a synergistic way, because coupled human-environmental systems must not necessarily evolve to achieve maximum efficiency, neither do they only change gradually. Altruism and cooperation as well as resilience theory have shown different behaviors of such systems and actors involved. More of that further below.

The constraints and methodological drawbacks of standard economic theory when it comes to environmental goods, are the main reason for Gowdy to question the usefulness of economic valuation of biodiversity and ecosystem services in that framework.

First he notes the different conceptions of value in ecology and economics. He defines economic value as "indicated by relative prices determined by market exchange" (Gowdy (1997b), p. 25). Because markets tend not to work perfectly, economists came up with ways to measure value that is not correctly expressed through market exchange. The two most prominent approaches are hedonic pricing and contingent valuation, which we have already discussed above and which are also part of the TEEB methodology.

In the following Gowdy notes the problems that arise with this kind of valuation methods: the different behavior of people whether they are asked to make a decision as consumers or as citizens (for a nice example see ibid. p.31), and the missing justification to use willingness-to-pay over willingness-to-accept measures, because willingness-to-pay statements tend to underestimate the value of environmental features. Further problems encompass the moral decision whether it is adequate to: apply discounting rates to long-lived ecosystems and provision of their services, reduce the whole range of values found in ecosystems to a single denominator like money, (also known as the "incongruity problem"), and what to do with pure uncertainty. Also marginal analysis of value, common in standard neoclassical economics, tend to be problematic in the face of interconnected ecosystems with complex food-webs, where the extinction of any one species may lead to large alterations in the whole system, which may through a marginal change cross a threshold. Although the TEEB framework is more advanced in methodology of valuation, for example it also includes deliberative processes, these problems remain pretty much unsolved.

The main crux is that many biologist firmly believe that the value of biodiversity is essentially infinite, partly because there are no substitutes for species gone extinct, and because recovery from mass extinction does happen far too slow for human civilization to endure it. All of this cannot be captured in a valuation framework that is solely based on market exchange. Furthermore it is problematic to infer social welfare from choices made by individuals in market situations, which is the way neoclassical economics works. What an individual wants is free from ethical or moral judgment, but it was shown that people make more egoistic choices when reacting only to a market signal rather than choosing in a broader societal context, which is frequently much more realistic. Spash and Hanley (1995) concluded from the high occurrence of lexicographic preferences in a mixed student and public sample, that the use of the contingent valuation method in determining the value of biodiversity should be questioned. They found in their study that 23.2% of the public sample stated that ecosystems and species should be protected no matter how high the costs for society would be and refused to give a willingness-to-pay amount. Lexicographic preferences means exactly this: individuals prefer one option absolutely over another option and they are unwilling to make a trade (Gowdy, 1997b). Therefore no other value than infinite is given to environmental goods and services which makes valuation in terms of money or utility useless.

To manage and conserve biodiversity Gowdy concludes with a list of policy advices which include: finding a single measure that would show the total value of biodiversity is impossible, therefore it is necessary to conduct multiple assessments that include collective choices of people as citizens; adopt a strategy of ecosystem management, fitted in the geographical and societal context of the area; go beyond cost-benefit analysis; and finally expand safe minimum standards.

An interesting take on the topic of valuation methodology was also provided by Nunes and van den Bergh (2001). They note that "monetary valuation of changes of biodiversity can make sense. This requires [...] that a concrete biodiversity scenario is formulated, that a multidisciplinary approach [...] is used, and, [...] that the change is well defined and not too large." (ibid., p.218). It was also clear to them that "the assessment of biodiversity values does not lead to a univocal, unambiguous monetary indicator." (ibid., p.218).

An approach to broaden standard valuation methods are focus group discussions with different stakeholders, which enhance the participants knowledge, ensure informed decisions, and lower the inconsistency and variability of value estimates. Exemplary studies were conducted by Christie et al. (2006); Fischer and Young (2007).

What the public knows about biodiversity 'a priori' is topic of the next section.

6.3 Knowledge, education, awareness - status quo

In addition to the behavioral differences that people show in different situations, often their knowledge about the subject matter is far from being complete.

Spash and Hanley (1995) have shown that "lack of knowledge about the meaning of biodiversity seems prevalent" (ibid. p.203), both in students and even more in the general public. 37% of the students where totally unfamiliar with the definition of biodiversity provided. In the public sample the number was as high as 71% . In a similar study Lindemann-Matthies and Bose (2008) showed that 60% of the participants had never heard of the term biodiversity. Their sample consisted approximately half of grammar school pupils and half of adults. Although lack of knowledge about biodiversity was higher in young people (77% had never heard of the term), it was still considerably high in non-graduate adults (59.4%), and moderate in graduates or students (29.7%). Both studies showed a positive relationship between education and knowledge about biodiversity. Similar conclusions were drawn in a completely different setting, namely a national park in Benin (Vodouhe et al., 2010).

Schlegl and Rupf (2010) confirmed that higher levels of education correlate with positive attitudes towards fauna (see references therein). They also found out that species that could be identified and named ranked higher in affinity ratings in students across different educational levels (from primary school to university). Interestingly the causes for higher affinity, as stated by the participants, was if species were 'rare, worthy of protection' and/or 'beneficial', which implies a certain knowledge of ecology.

In her review on the situation in the United States, Malcom (2001) notes that whereas 73% of adults know about the direct relationship between species loss and habitat destruction, only 2 out of 10 surveyed people knew the term 'biodiversity' and had heard about the loss of biological diversity. Although there is wide support for conservation of biodiversity (83%) in the public, this support is shallow and biodiversity not on the top of the list of most people's worries. This may be due to the lack of knowledge about the seriousness of the problem. For example "only 38% of science teachers rated themselves as being very familiar with the concept of biodiversity" (ibid., p. 392) and the majority of them did not believe in the threat of a mass extinction, even if they were familiar with the current biodiversity crisis. In addition there are only a few university programs that include biodiversity research as an area of major interest, and a general decline in student interest and teaching effort in systematics is prevalent.

The evidence collected here supports the statement that knowledge and consequently awareness of biodiversity related issues is limited. This is in parts caused by a lack of formal education, but also connected to low levels of informal (media coverage and other) transmission of the subject, leading to a largely uniformed public, even at levels of relatively high education.

But education may not always motivate people to make a contribution to a public good, like conservation of biodiversity or protection of ecosystems. Siebenhüner (2000) notes that economics students act more self-interested and are more likely to free ride (it is cheaper not to contribute to a common good, by concealing ones interest and letting other people pay for the provision and maintenance of the good (Common and Stagl (2005)) in game theoretical experiments, than students from other disciplines. Furthermore it was shown that this is because of the exposure to the standard economic model of *homo economicus* in the course of their education and not because of the previous selfish character of the students.

Surprisingly standard microeconomic textbooks do not elaborate in depth about why one should assume maximization of personal utility the main determinant for people's behavior (van den Bergh et al., 2000).

This leads us directly to the important differences in how the individual is perceived in standard economic theory as opposed to other, less reductionistic, scientific approaches.

6.4 Different conceptions of the individual and consequences for biodiversity conservation

Summing up all the different approaches to identify and explain human behavior is a nearly impossible task. Research concerned with that topic spans a wide variety of different scientific disciplines and attempts to depict the behavioral complexity of humans should be advanced through a multidisciplinary scope (see Gintis (2009)). We need to define a guiding concept of the human actor to facilitate understanding and shaping of human-environmental relationships in the context of biodiversity conservation and sustainable development. Following the general focus of this thesis on the value of biodiversity and ecosystems, be it economic or otherwise, I will include criticism of and alternatives to the standard model of the individual in economic theory, namely the *homo economicus*. For that purpose I will draw on literature from Ecological Economics, Experimental Economics, Evolutionary Biology and Happiness research.

In standard economic theory the individual is presumed to be rational, self-interested and utility-maximizing. It is expected to make decisions rationally, which means that it will be able to choose out of a set of alternatives in a way that will ultimately maximize its own benefit. For that to be possible it is necessary to have complete and perfect information about the different options and to formulate preferences in an ordered and transitive way, meaning that the order of the preferences is fixed and that if option A is preferred over option B and B is preferred over C, than A must also be preferred over C. Maximization of utility in that respect is the choice of an optimal consumption bundle, which is completely preferred over all other consumption bundles and can be afforded within a constrained budget (of money). The consumption bundle is characterized by full substitutability between goods. Additional axiomatic claims about this kind of behavior are non-satiation and strong monotonicity: the individual is never satisfied in maximization of personal utility, and more consumption of one good does automatically lead to more utility and personal well-fare. (van den Bergh et al., 2000).

Following the philosophical tradition of logical and empirical positivism, the maximization hypothesis became the 'paradigm' of neoclassical economics. In the sense of Kuhn it is an untestable, unfalsifiable, axiomatic and metaphysical assumption. It is also an example for methodological individualism, where social phenomena can be explained by adding up from the behavior of isolated individual actors. (van den Bergh et al., 2000).

This clarifies the explanatory power of the maximization methodology in modeling behavior and making prognoses. However the facts that decisions are always embedded in an ethical and social context (Siebenhüner, 2000) and that people act differently when making decisions in the role of a consumer or a citizen (van den Bergh et al., 2000) are totally left out. Further criticisms of the model can be clustered broadly into the three following categories:

- Evidence from (Behavioral) Economics: Transitivity of preferences is not always given. Human behavior is often irrational because of incomplete information, or because it is driven by temptations rather than logic. Utilitarian discounting in decisions made into the future was not consistently reflected in experimental settings. Satisfaction through consume does not only come from the good itself but also from the way it is obtained. Market demand is not the aggregation of independent individual demands. In addition to the budget also time, social norms and rules and institutional settings act as constraints for individual choice. Certain environmental functions cannot be substituted for. (van den Bergh et al., 2000; Siebenhüner, 2000).

  Finally and very importantly it was shown that people do not exclusively act in a selfish way. There is clear evidence for altruistic and reciprocal traits in human behavior, which are firmly grounded in

- Human Evolutionary History: Whereas reciprocal altruism (acting selfless because of expected return of the gesture) and extended kinship (i.e. securing the propagation of one's genetic inheritance through cooperation with related individuals and social groups) can be explained in terms of long-term self-interest, there is convincing evidence that human traits of cooperation exist that do not fit this profile. Gintis (2000) termed this predisposition to cooperate and punish defectors, without expecting any return, *strong reciprocity.* From the theory of reciprocal altruism we can easily infer that, when chances are high that the group will disband, self-interested actors will stop cooperating, because they cannot expect a return of their favors. In situations where the survival of the group is threatened and it is most desperately in need of stable cooperation, reciprocal altruism alone does not guarantee stability. Eventually the group would collapse. From such a perspective strong reciprocity might have an evolutionary advantage, as strong reciprocators will also stimulate cooperation in such situations, even if they face a reduction of personal fitness. In that case group benefits outweigh individual costs. It was empirically shown that in every population a fraction of people act as strong reciprocators, even under total anonymity and with no further encounters with the receiver of cooperation or punishment. In his conclusion Gintis (2000) notes the "prevalence of strong reciprocity in the everyday operation of human society" and that "[w]ithout strong reciprocity, then, human society would likely be [...] less successful as a species." (ibid., p. 177, 178).

Summing up empirical studies with subjects from very different social, socio-economic and cultural realms Gintis et al. (2003) concluded that "the canonical model of self-interested behavior is not supported in *any* society studied." (ibid., p. 158). Of course they observed considerable variability in their results, depending on market integration and patterns of economic activity of the studied groups. Another important characteristic of strong reciprocity is that "it unambiguously favors intentions over outcomes" (ibid., p. 162). A strong counterpoint to the utilitarian perception of human behavior, which is characterized by consequentialism (Screpanti and Zamagni (2010)).

- Normative assumptions and following environmental implications: It was already noted above that the exposure to the model of *homo economicus* can shape student behavior, but it is also the "ideological basis for market economies regulated [...] on the basis of egoistic motivations." (Siebenhüner (2000), p. 17), it "generally hinders altruism and responsibility for other people and future generations.", and it "causes an increasing number of people to feel socially isolated and alienated from their natural and family roots." (ibid., p. 18). This leads to feeling less responsible for the global commons and increases environmental degradation.

Alternative conceptions of the human actor were presented in literature, which can help to expand (not dismiss) the narrow concept of the *homo economicus*. Important features of these alternative theories will be the topic of the next paragraphs.

To address the problem of incomplete information Herbert Simon's *principle of bounded rationality* can be incorporated into the decision making process. Bounded rationality is a theory of choice that takes into account the limited capacities of the individual to 'compute' all the possible alternatives, to choose the optimal one and to be aware of all consequences of this choice (Callebaut, 2007). To make a rational choice, therefore is virtually impossible, because the human mind is not equipped to solve the multitude of complex problems, we are facing in the real world, in a complete and optimal way (van den Bergh et al., 2000).

Then how do we make decisions? The answer H. Simon provides is the *satisficing* principle. A mix of the words 'satisfaction' and 'optimizing', satisficing means to choose an alternative that meets or exceeds the individual's level of aspiration, but which is neither necessarily optimal nor unique. In the real world people tend to stop searching and settle for an acceptable alternative, after having spent a certain amount of time and energy. When and why this happens does to parts depend on previous experiences. (Callebaut, 2007). A thorough response to the claim that *satisficing* is simply optimization under constraints can be found in Callebaut (2007). Therein the author notes that one cause for the importance and uniqueness of Simon's theory is its anchoring in evolutionary and environmental processes. In addition to computational limitations, dealing with the 'structure of the task environment' is an important part of making a decision.

Further alternative models (summary based on van den Bergh et al. (2000)) of human behavior encompass:

Lexicographic preferences, which we have already discussed above.

Habitual behavior and routines, both of which are regarded as tools to deal with uncertainty, complexity and change. But acting according to routines or habits does not fit into the standard model, because the behavioral response is already determined through experience and learning, without considering competing alternatives.

Incommensurability, which means that the multiplicity of the different aspects of an object, or good, or ecosystem services, for that matter, cannot be described within a single framework (money, energy, mass, etc.). Incommensurability is the basic assumption in multicriteria evaluations.

Behavior facing risk and uncertainty, which often takes paradoxical forms (individuals may change from risk averse to risk loving, when external conditions change). Theories fitting in here (*Regret theory, Prospect theory, Girardian economics*), altogether lead to question the applicability of a theory of maximization of expected utility as being adequate for dealing with real-world decisions about environmental change.

Irrational behavior can often be observed when people are driven by strong emotions. Such decisions are often unconsciously made and without purpose, which means that they cannot be explained in a deterministic logical framework.

Cognitive dissonance, the idea that preferences adapt to decisions and not the other way around, which breaks the logical chain of argumentation in standard economic decision theory.

Authors have come up with conceptions of the human actor different to the *homo economicus*, which are more sensitive to the behavioral complexities discussed above. This is an important task because environmental management strategies and policies solely relying on the neoclassical model, are likely less effective or bound to hit roadblocks on their way to implementation. Due to false assumptions about the way people make choices, a behavioral trait that is supposed to be predictable in the standard economic model, van den Bergh et al. (2000) note "an optimistic attitude towards price-based instruments" (ibid., p. 55) in the standard framework. In the following paragraphs and pages van den Bergh concludes that caused by high levels of uncertainty, which are often encountered in the context of environmental problems, exactely those price-based instruments are prone to be less effective and efficient.

Further implications of alternative behavioral models include that people perceive losses and gains differently, which is the main point of regret and prospect theory. People also tend to be unwilling to make trade-offs in the case of immaterial gains that relate heavily to well-being. This can be linked to endogenous preferences, which stem from the inside of the individual, are dynamic and can change, which leads to lexicographic ordering of expressed preferences.

Therefore one possible venue of policy intervention could be to change endogenous preferences, via media channels, education and cultural norms and rules, but doing so calls for an interdisciplinary or better transdisciplinary approach.

One possible explanation why people express lexicographic and other 'illogical', non-transitive preferences when making decisions concerning the environment and the diversity of life, can be found in E.O. Wilson's *Biophilia Hypothesis*. Wilson states that humans have an "innate tendency to focus on life and lifelike processes." (Gullone (2000), p. 294, original reference therein). Further he notes that "the natural world is the most information-rich environment that people will ever encounter" (Miller (2005), p. 433), and therefore serves as a vital component in the healthy development of high-order cognitive function.

Wilson finds prove for the tight relationship between nature and humans in gene-culture co-evolution that has taken place nearly exclusively in tight contact with nature, during the course of human evolutionary history. Learning, remembering and finding new ways to adapt to environmental challenges was a necessary precondition for survival and reproductive success in pre-industrial societies, and the human brain has evolved in that context. Today highly synthetic and manufactured urban environments exist that our brain may not have had the chance to adapt to, which may consequently lead to reduction in well-being and higher incidence of psycho-pathological diseases. Although the empirical data supporting this claim are equivocal, it was shown that people across cultures express higher affinity towards natural rather than urban sceneries. (Gullone, 2000).

Miller (2005) notes that the 'extinction of experience' with nature is also a major factor inhibiting the successful conservation of biodiversity. In his eyes, urbanization is the main cause for people's estrangement from nature. It is necessary to provide natural landscapes near urbanized centers, especially to support mental and emotional development during childhood, but also to promote well-being across the whole population. Frequent encounters with nature that foster affection and creativity, and that make obvious "the inescapable biological dependency of human life on nature" (Becker (2006), p. 20), are also central features of Becker's *homo ecologicus*.

A positive emotional relation with nature and it's different entities is also a prerequisite for Siebenhüner's *homo sustinens*, a conception of the human being "living according to the requirements of sustainability" (Siebenhüner (2000), p. 19). He notes that "it seems to be a universal human trait to feel some kind of happiness in intact natural scenery." (ibid., p. 19) and that "the predominance of economic rationality has curbed nature-related emotionality and led to often unhealty results." (ibid., p. 20). Further characteristics of the *homo sustinens* are:

- A tendency to communicate and cooperate, and to conserve and protect common-pool resources, rather than exploiting them selfishly (see also Ostrom (1990)). The connection to altruistic behavior, kinship and strong reciprocity (see above) is evident. To ensure such cooperation, healthy and fair communication is a must. Platforms of exchange in that respect must be open to everybody.

- The capability to learn and be creative. It is important to admit that learning is more than a conditioning process, and to foster system thinking during the learning process. We need to understand the creative and emotional aspects of learning. The first especially in social learning processes, which can lead to totally new ideas or ways to deal with a problem. The second in childhood and adolescence via connecting the intellectual topic with emotional affection, promising and necessary to convey more importance to biodiversity.

- The inclusion of moral and ethical dimensions, that have a great influence on personal and collective motivation. To include these aspects of the human as a social being is vital if the goal is to change values and lifestyles towards more responsible consumption and convince others to do so too. Also the "most durable and intense motivation" (Siebenhüner (2000), p. 22) to engage in collective action to conserve environmental features is intrinsic, coming from within. This in turn is closely related to self-determination and the right to choose freely and without constraints.

In conclusion Siebenhüner states that institutions that are based on the highly abstract and formalized notion of human behavior, that is the *homo economicus*, do not promote sustainable development. The same holds true for biodiversity conservation, which is an element of, and prerequisite for, sustainable development. But biodiversity is also a characteristic feature of complex-adaptive systems, which further complicates management and calls for more differentiated action than proposed on the grounds of the standard economic framework.

6.5 Complex-adaptive systems: Thresholds, Tipping Points and Resilience

Ecosystems are complex-adaptive systems which exhibit certain characteristics that one must consider when trying to manage them in a sustainable way. Not only ecosystems can be defined in this way, coupled human-environmental systems show similar dynamics and the economy was also defined as a complex-adaptive system (Ramos-Martin, 2003), but let us first focus on natural systems.

Ecosystems evolve and adapt according to internal dynamics as well as to changing external conditions. This change is neither gradual nor purely chaotic, it rather has an episodic character: slow processes of growth and organization are interrupted by sudden rare events of disturbance. These events may be of natural origin, like a forest fire through lightning, or may be due to anthropogenic influence on the system, like land-use change for agricultural purposes. Seemingly catastrophic events may also be an integral part of the dynamics of some ecosystems, an example being the above mentioned forest fire that releases a huge amount of locked-in nutrients (in the form of ashes of burned down trees) and is a critical factor in the rejuvenation of the system. Some plants even need the fire to stimulate the germination of their seeds. (Gunderson and Holling, 2002).

It is also suggested that an intermediate amount of disturbance in a system does enhance biodiversity (Molino and Sabatier, 2001). After such a disturbance a slow recovery and reorganization of the system to it's previous, or a functionally similar state can often be observed.

Often though ecosystems can exist in multiple alternative states. These multiple equilibria also have different functional characteristics. In contrast to a 'normal' disturbance, after which the structure, diversity and resilience of the system remains unchanged, unprecedented disturbances or disturbances at times or places of high vulnerability and low resilience, may flip the system into a fundamentally different, often degraded, state. These flips are often irreversible or only very slowly (in timescales beyond human appreciation) reversible, which makes recovery through management intervention very costly if not impossible. The processes that lead to such a sudden catastrophic change show non-linear dynamics and the further development of the system once such a threshold is breached is marked by a huge amount of uncertainty and unpredictability. Processes of change take place on very different scales, both geographically and temporally, with a number of feedback loops between slow, fast, big and small variables. (Gunderson and Holling, 2002).

Gunderson and Holling (2002) have provided a very clear and helpful visualization of the dynamics of complex-adaptive systems, namely the 'adaptive cycle', which they then expanded into the 'panarchy', that shows a set of nested adaptive cycles on different scales plus the various feedback loops between them.

If we follow the movement of the cycle we must consider the different speeds of change and the different magnitudes of stocks. The initial take-off phase r is characterized by an exploitation of existing resources, slowly accumulating the basis for the K phase. During the move towards K stability and connectedness in the species community rise, leading to a stable standing stock of a few dominant species and scattered patches of higher diversity. Up to the end of the K phase the system becomes more stable but also more rigid and vulnerable to disturbance, the resilience of the system diminishes. A shock then triggers the rapid destruction of the standing stock and a fast release of a huge amount of resources and energy. The potential for change is now very high in the system as reorganization sets in. The exit from the circle indicates the probability of a flip to an alternative state. Often resources are lost during this process and the new system becomes less productive and less organized. See figure 2 (Gunderson and Holling (2002), Chapter 2).

Such a flip is mostly not exclusively influenced by the one system on a single hierarchical scale, because the system is normally embedded in a broader context of one system at a larger and slower scale, and one system at a smaller and faster scale. These three adaptive cycles constitute the minimum requirement for a panarchy. In times of low resilience and high vulnerability, processes on a lower level can influence the development on the intermediate level. On the other hand the higher level system may contain the structure and resources that will guide successful reorganization on the intermediate level after a shock. Extraordinarily large disturbances can also cascade through the different levels, which may create opportunities for novelty and change, but can also lead to a collapse of the whole panarchy. See figure 3.

The 'Big Five' mass extinction events in earth history are examples for collapsing panarchies, because they affected the natural world on all scales, from genes to species to ecosystems to biomes. These events did not only lead to the extinction of species but also to the destruction of ecological niches, which need to be rebuild before they can be recolonized again. This is a

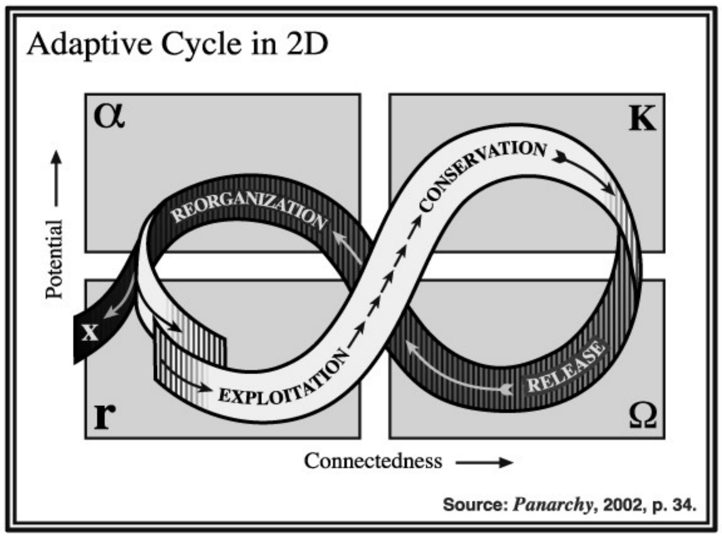

Figure 2: Adaptive cycle (*source*: Gunderson and Holling (2002))

likely explanation for the long recovery times (at least 10 million years) from such events. (Gunderson and Holling (2002), Chapter 3).

Resilience is changing as we move around the loop in the adaptive cycle. It shrinks on the way to the K phase and expands rapidly in the phases of release and reorganization. Resilience sensu Holling means "the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior." (Gunderson and Holling (2002), p. 28). This is an important conceptualization of the system's ability to the continued provision of goods and services. If the resilience of the system is low a small disturbances may be enough to flip the system into an alternative state, that does not ensure stable provision anymore, which in turn may very well lead to losses in human well-being. A well-known example in human history is the demise of the civilization of the Easter Islands. The population managed to deforest the island in a few hundred years, using the wood in construction of houses, canoes and for transporting the enormous ritual statues. Consequently tree species have become extinct and soil erosion took place, leading to severe scarcity in timber. Eventually

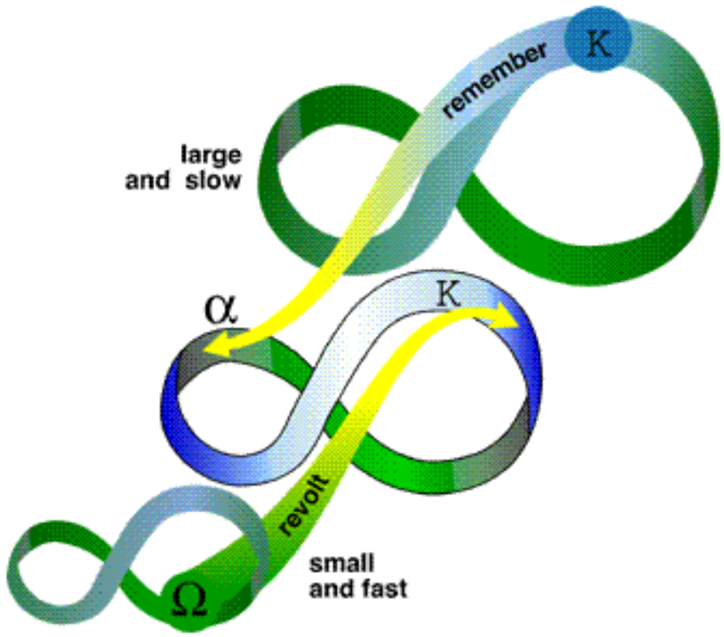

Figure 3: Panarchy (*source*: Gunderson and Holling (2002))

the inhabitants of the island couldn't build canoes anymore to hunt porpoise which had been the staple food source until that time. In the following the civilization gradually collapsed in famine and war. It was shown that the Easter Island development is not the only case of overexploitation followed by collapse in human cultural history. (Gunderson and Holling (2002), p. 116ff.).

This leads us directly to the inevitable connection between ecological and social systems, which rely strongly on resilience to maintain their productive and protective state for human well-being. Resilience again is connected to and partly fostered by sufficiently high levels of biodiversity. Before we try to identify the implications of complex-adaptive systems theory on coupled human-environmental systems, we should first clarify the nature of catastrophic regime shifts in ecosystems.

It was shown that while ecosystems normally respond to gradual environmental changes in a smooth way, sometimes a sudden dramatic flip can occur, which is often caused by an unpredicted event and leads the system into an alternative state. It is also widely acknowledged that resilience is the main determinant of whether this is happening or not. It was empirically shown that some ecosystems have two alternative 'stable' states in which they can exist. Shallow lakes for example can suddenly flip from clear to turbid conditions if a tipping point is reached. Normally this happens via anthropogenic nutrient input (runoff) and leads to an undesired state. Similar examples can be found in coral reefs changing to brown fleshy algae, woodlands to open grass lands, arid and semi-arid lands to deserts, and flips in oceanic systems which may lead to collapses of fisheries and the stop of the 'global conveyor belt', an ocean circulation system of major importance for regional climate in North America and Europe. What all of these examples have in common, is that they represent a move towards an undesired state, at least a state with lower diversity, and that they are almost exclusively triggered by human action. Another common characteristic of the regime shifts observed in the examples is the difficulty to restore the previous state. Often the new state is irreversible. Even if slow gradual changes, like climate warming, may not have an direct effect on the probability of such regime shifts, they do very well alter the resilience of the system, potentially making it more vulnerable to crossing a threshold and tipping over in the face of stochastic disturbances. That is why management should focus on maintaining resilience. (Scheffer et al., 2001).

Maintaining resilience can be approached via maintaining high levels of diversity. A management approach should be adaptive and co-evolutionary, meaning that it is able to co-evolve with the problem task. This can happen via different routes, including modeling complex-adaptive systems in an interdisciplinary framework, active participation and social learning (see section 6.6), as well as institutional change. (Rammel et al., 2007; Horan et al., 2011).

Obviously there is a critical need to predict regime shifts to avoid them or at least cope adequately with the consequences. Sadly it is often not after the flip has happened that the underlying causes are investigated. One documented case is the collapse of the Canada's Newfoundland cod fishery in the early 1990's which had large economic and social repercussions in the area. Although there has been a ban of fishing since over 15 years, the stocks have only shown little signs of recovery (Biggs et al., 2009). It shows clearly that society is desperately in need of uncovering and describing thresholds in coupled human-environmental systems to avert collapses. The first step herein is to determine early-warning signals through mathematical modeling.

Scheffer et al. (2009) have found some generic early-warning signals that apply to a number of systems when a critical threshold is near. The most prominent indicator is *critical slowing down*: the system becomes increasingly slow to recover from small perturbations. The rate of recovery (from an experimental perturbation) in turn can be used to determine how close a system is to a tipping point. Such monitoring is impossible most of the times in natural systems, but close to a critical transition critical slowing down leads to an increase in *autocorrelation*, the second important warning signal, which can be observed far ahead of the flip. Autocorrelation describes the situation where intrinsic rates of change or fluctuation in the system decreases. The state of the system at any point in time becomes more and more similar to the state before. The increase in 'memory' saved and expressed in the system can be measured and used as an indicator. The third signal is *increased variance*, which means that the impacts of shocks add up in the system and the intrinsic fluctuations of the system become more variable. Although that is somehow counterintuitive to the effect of critical slowing down it was also detected in model runs. A system will stay longer near an unstable point before tipping than after, because the rates of change slow down. It can also exhibit flickering back and forth between the two alternative states. It may also show significant alterations in spatial patterns, like increased coherence. These are additional interesting attributes of systems approaching tipping points. Although the early-warning signals that Scheffer et al. have described were derived from relatively straight forward mathematical models and the real world doesn't always coincide with those, resemblance to prove was found in the spatial organization preceding desertification and in increased fluctuations in fish populations near to collapse due to harvesting, as well as in the dynamics of financial markets.

These theoretical and technical approaches to manage changes in complex-adaptive systems are an important first step to uncover the nature of what we are dealing with. The question still remains what can we do with this knowledge to mitigate against the deterioration of ecosystems and the biodiversity they inherit? How can broad public support and willingness to act be sparked, which are needed to make a significant and lasting change? The inclusion of stakeholders in the whole process, from the generation of scientific hypothesis, over the design of experiments, to the interpretation of the findings, and the suggestion and implementation of solutions, may prove to be a successful pathway in this direction. The next section will deal with an ambitious methodology of that sort.

6.6 Participatory governance and social learning

So far I have discussed economic valuation and management of complex-adaptive systems as two strategies to cope with the loss of biodiversity. I have also mentioned that it will be necessary to find more effective ways to raise public knowledge, concern and awareness of the topic. Ultimately the whole thesis deals with fighting the causes of inaction and finding alternative theoretical and practical approaches to solve this global complex problem, but there is only so much space here to explore some of the options in depth. Because there won't be any single-measure solutions, no omnipotent panacea, this is probably not such a big obstacle to sketching some sort of 'clumsy' solution that consists of a diverse approach with influences from very different fields of scientific inquiry.

To move from a scientific solution to a societal one requires some sort of political implementation, which in turn is morally only feasible when based on democratic institutions. But as Fung and Wright (2001) note, the common form of liberal democracy today, which consists of representative democracy plus bureaucratic administration, seems "increasingly ill suited to the novel problems we face in the twenty-first century." (ibid., p. 5). The loss of biological diversity is one of those novel problems. Under the umbrella-term of 'governance', which was defined as "the informal and formal processes and institutions that guide and restrain the collective activities of a group." (Renn et al. (2011), p. 232), authors with a background in political science have provided innovative approaches to include the voice of the civic society into the decision-making process. Active participation of a group of stakeholders, including politicians, experts, managers and lay people, holds considerable advantages over a simple voting procedure. "In addition to being intrinsically valuable [. . .] participation has the potential to achieve more efficient and equitable outcomes in [. . .] management of common property resources [. . .]" (Osmani (2008), p. 4).

This being the case, public participation should be included into the approaches to safeguard our planet's biodiversity, as a facilitating mechanism to make good decisions. This is rather accomplished through governance than through conventional political tools, because governance in it's structure is non-hierarchical and acknowledges that a political decision should be made not by the state as the sole actor, but by a wide variety of stakeholders, including scientific communities, industry and the public. In the process, power is distributed among these actors and they have the opportunity to express their own individual interests in an equitable fashion. The ultimate outcome is a binding political program, that was advanced through a deliberative group choice following in depth discussion of the different proposals. (Renn et al., 2011).

In their article Fung and Wright (2001) trace back the recent "erosion of democratic vitality" (ibid., p. 6) to the complexity and size of the problems that modern (global and regional) politics has to deal with. This unhealthy situation calls for new ways to come to political solutions. Fung and Wright therefore introduce the notion of *Empowered Deliberative Democracy*, EDD in short, which "presses the values of participation, deliberation and empowerment to the apparent limits of prudence and feasibility." (ibid., p. 7). To demonstrate that EDD has big potential not only as a theoretical concept, but in practical appilicability the authors include five case studies on participatory deliberative governance in the paper, one of which is governance of stakeholders under the U.S. Endangered Species Act.

When it first was introduced the U.S. Endangered Species Act was rather the opposite of deliberation, working with strict regulations and bans of development and exploitation of natural resources. After some time a permit system was introduced that allowed environmentally sound development. The proposals for the most advanced permits were constructed via a process that included environmentalists, developers, and community speakers, creating highly sophisticated management plans that have proven to be effective and adaptive. In addition to these advantages, stakeholders included in the process are empowered through the sharing of responsibility, which creates a wide acceptancy, because of the chance to voice personal ideas and critiques prior to the decision, which is not imposed on them in a top-down fashion. Of course that must not mean that everybody is happy with the outcome, but even if there are winners and losers facing the outcome, the way how and why the decision was made will be transparent and understandable (in the perfect scenario). Furthermore there is a direct incentive in spending time and energy in forming a decision (accquiring necessary knowledge and trying to understand other people's interests that may differ from, or conflict with personal ones) and participating actively in the process, because whatever decision is made it will influence the participants and the community rather directly.

Following the methodology of Fung and Wright, EDD consists of three general principles: a focus on specific and tangible problems, the involvement of ordinary people affected by these problems, and a deliberative development of solutions for these problems. Institutions that serve to facilitated EDD should go after three basic design principles: the devolution of public decision authority to empowered local units; the creation of formal linkages of responsibility, resource distribution, and communication in between these units and between the units and some sort of centralized authority; and finally the use and generation of new state institutions to actively support and guide in the process. (see Fung and Wright (2001), p. 17).

Further statements from Fung and Wright that should be mentioned are:

- The role of the expert in the EDD process is in aiding the decision making and voicing what he or she believes is the best solution. He or she has no exclusive power to make important decisions.

- Both, individual motives of the participants, as well as institutional design shape the decision making process. Power relations must be uncovered and manipulation of participants must be prevented.

- Participants may change their personal preferences during the process or form completely new ones.

- In contrast to anonymous voting procedures, participants in EDD settings are forced to take the needs and wants of the other participants into account while making a decision, but it is often hard to aggregate the individual preferences when the problem involves high levels of complexity and uncertainty.

- Devolution does in fact require "the commensurate reorganization of the state apparatus" (Fung and Wright (2001), p. 21), which is a formidable task including the breaking up of heavy and rigid systems of power and control.

- For a localized EDD system to work properly there is still a strong need for centralized coordination, monitoring, assistance and sharing of knowledge.

- In theory EDD reforms essentially transform official institutions, "colonize state power" and "try to change the central procedures of power" (ibid., p. 23). The goal is to institutionalize public participation as the main tool for decision making, especially when public goods are concerned.

- Finally EDD procedures must be effective: the outcome must help local communities to deal with a certain problem. In the process learning abilities are present and knowledge about the problem is heightened in the whole system of participants, community and (institutional) environment. EDD procedures must also be equitable and fair, including especially people that are often unable to voice their concerns, like the poor. And they must strive for deep and ongoing participation, through establishing new channels for participants to voice opinions and through giving them the "real prospect of exercising state power" (ibid., p. 27). To ensure working participation, the information loaded on public participants cannot be too extensive, neither can the geographical scale or time horizon be too broad to grasp by individuals. Final decisions should be well informed and reached via fair and (fairly) rational discussions. An additional merit of participation here is that people gain politcal skill as well as factual wisdom during the process, which allows for the prediction that such processes will gain in quality the more they are applied.

This is a very condensed summary of the work of Fung and Wright, the different principles are discussed very comprehensively in the paper. I do not have the space here to go much further into depth, but some additional remarks applying to the theory of EDD should be made, that seem of importance to the questions of this work.

Of course there are also drawbacks, traps and unsolved problems to the EDD framework, which include the applicability of the theoretical framework to the real world case studies and the inferences that can be made from this fitting exercise to future applications, as well as criticisms of the model itself. Including, i.a. external limitations, internal imbalances in power and influence, and problems in defining, finding and selecting participants. As Fischer (2006) notes: "[C]itizens can participate but [. . .] participation has to be carefully organized and facilitated, even cultivated and nurtured." and "[C]itizens participation schemes rarely follow smooth pathways." (ibid., p. 21 and 22).

It is obvious that in the case studies presented in Fung and Wright's paper the methods of governance used were crafted to fit a concrete problem. Dealing with the loss of biodiversity may not fully fit into this criterion, because this problem is heavily interrelated with other phenomena of global change, like climate change, pollution, forest clearing, exploitation of marine resources, etc. The case study about the U.S. Endangered Species Act does not have this level of complexity, as it is geared mainly towards the protection of single species and their habitats, but not on the protection of ecosystem functioning on a big scale. Whether the EDD framework, as it is explained here, does apply to the problem of biodiversity conservation on a global scale remains unanswered.

But after all the ongoing erosion and overexploitation of the global and local public commons highlights the inability of the current political system to deal with these problems adequately. This calls for new, innovative and maybe bold alternatives, of which EDD is certainly one.

Renn et al. (2011) expand the term governance with the notions of complexity, uncertainty, ambiguity and risk. The methodology they call *risk governance* is explicitly geared towards problem-solving that includes dealing with these characteristics of so-called 'systemic' risks. Loss of biodiversity and the chance of following ecosystem collapse fall into this category. Complexity herein refers to the difficulty in identifying casual relationships between different levels of biodiversity and ecosystem functioning. Uncertainty stems from the lack of data to precisely predict the hazards of biodiversity loss. Ambiguity is a social criterion that reflects the different positions in a stakeholder framework, to whether risks stemming from biodiversity loss are acceptable or not. It refers to the different societal constructs of relevant risks. Renn et al. (2011) connect ambiguity to "the existence of multiple values" (ibid., p. 235) and they plead for the incorporation of different forms of knowledge to resolve ambiguity, which is often the cause for imbalanced action or inaction.

To deal with such a problem setting, risk governance is inherently contextual and consists of "continuous and gradual learning and adjustment" (ibid., p. 236). The management approach of risk governance, which is only the last part of the process following pre-estimation, interdisciplinary risk estimation, risk characterization, and risk evaluation, aims at either eliminating or mitigating risk potential or increasing (societal) resilience. This applies to the situation where the risk is considered intolerable. In refering to the evidence collected in this work, I consider the loss of biodiversity in such a way.

Also part of the problem is that uncertainty involved cannot easily be reduced, and may be irreducible after all with today's computational abilities. In such a case Renn et al. (2011) advise for management based on the principle of precaution. Whether or not the biodiversity problem is one that shows high ambiguity is not easy to answer, because overall knowledge of the problem is low, but people normally hold high moral values of nature (see results, section 10).

In any case the key to successful risk governance is mutual communication in all stages of the process, which goes beyond top-down, one-way transfer of knowledge, and fosters social learning. Again the problem arises of who should be included in the process. Renn et al. (2011) state that "the more actors are involved [...] the more socially robust the outcome." (ibid., p. 243).

To respond even more specifically to the challenge of biodiversity conservation the work of Underdal (2010) should also be mentioned here. He writes about long-term environmental governance and adds to the difficulties, already described above, the long time lags between (political) action or inaction and environmental responses, and the fact that we are dealing with global collective goods or commons. Both characteristics of environmental problems make global action difficult, because for one, the time horizon of environmental change by far surpasses the one of political change (election cycles), and secondly, it is not sure whether the positive outcomes of E. Ostrom's analysis of local common good governance systems (Ostrom, 1990) fully apply in the global policy arena. The first point may be a disincentive for policy makers to invest a lot of time and energy in measures that won't benefit their voters in the near future or even in their lifetime, when elections are at stake.

The notion of discounting applies here, which is the economic method to determine the value a commodity has now with regard to its future value (Common and Stagl, 2005). Normally the present value is assumed to be higher than the value in the future, because of the assumption of people's preference for immediate consumption, and the reliance on steady economic growth, making the good cheaper in the future. Both assumptions are strongly contested in literature (see Underdal (2010)). But in any case future stakeholders are not present to voice their concerns in the decision-making process, which adds a normative dimension, of choosing what to preserve for the future and what to use up now, to the decision. The fair use of natural and human resources, securing development abilities and freedom of choice today and in the future is probably the main message of sustainable development, as already laid down in the Brundtland report (WCED, 1987). Questions surrounding the challenges of 'Earth system governance', including sustainable development and safeguarding of the environment, fall into the categories of 'analytical' (scientific understanding), 'strategic' (effective management), and 'normative' (societal, moral and ethical justification) (Biermann, 2007).

The second point (concerning global commons) refers to the situation that, in the case of biodiversity conservation, if a global effort is made in mitigation or adaption, than also those parties or actors in the global political system which did not contribute at all will benefit from the measures taken. On the other hand Underdal (2010) stresses that in the global political system blocking collective action is much easier than organizing it. In such a system with a huge number of different actors (politics, industry, social organizations, media, etc.) with different, often diametrical, agendas, which contribute to decisions often in an anonymous setting, the prevalence of free-riding is likely to be higher, than in small scale communities.

Underdal (2010) proposes two management strategies. On one hand the *collective action model*, which has contraction of power and centralized leadership as main features, relying on what he calls a 'synoptic master plan'. And on the other hand the *adaptive governance model*, which strives for diversity and pluralism in decentralized subunits, and is heavily linked to the concept of resilience. Whereas the first model is rigid the second is flexible. In the same time the centric approach guarantees faster action, (imposed) consistency and perseverance. There is not enough space here to compare the two approaches in their merits and drawbacks in full length. The overarching conclusion that Underdal reaches, is that which management scheme we tend to favor, relies on the task environment of the problem at hand. Of course in dealing with a complex problem like biodiversity loss, forming a definition of the task environment alone is already a formidable task, but a mix between the two approaches seems the most reasonable way to go.

A central feature of successful participatory governance processes is social learning, already mentioned above. Social learning has ties with the concept of bounded rationality, which we have already discussed, and is process oriented rather than goal oriented. As Garmendia and Stagl (2010) put it: " [R]ationality depends on the quality of the process that it generates." That depitcts what is called procedural rationality as opposed to substantive rationality, which strives for an optimal solution.

Social learning is used to enrich methods of decision making in general and also methods of monetary valuation. An uniform definition that pins down social learning is not given in literature, also because different disciplines, from political science to pragmatic philosophy have dealt with the phenomenon. For our purpose it is important to note, that social learning can help dealing with complexity and uncertainty, and that it goes beyond acquiring factual knowledge, in that it may foster understanding of differentiating perspectives and shape values of participants. It is also seen as a necessary route to increase resilience in socio-ecological systems and should be included in every participatory framework as a criterion of quality. (Garmendia and Stagl, 2010).

A similar line of argumentation was given by Norgaard (2004), who gives examples of how complex problems can be approach with a collaboration of scientists from different disciplines, which in turn needs facilitating institutions and social organizations. He therefore argues for the use of the concept of epistemic communities, consisting of scientists who share the same problem matter in their study, but not necessarily the same scientific origins. Norgaard states that we should focus on epistemic communities rather than on scientific disciplines, which he describes as historical artifacts, if we want to understand the structure of scientific knowledge today.

7 Dealing with the loss of biodiversity - A synthesis

I have touched a variety of very different topics in this work and tried to elucidate the problem of biodiversity loss and possible solutions in a holistic manner. I am quite aware that this is a task bound to fail in the face of the enormous complexity of the problem and the many different legitimate perspectives and approaches considering solutions, which root to parts in scientific fields that I have not had the chance to study thoroughly. But I strongly believe that such a multi-dimensional approach is the only viable option to deal with biodiversity loss, which is pressing and inevitable, even if the best outcome we can hope for are partial, clumsy solutions. I will try now, in the following paragraphs to sum up the whole of the theoretical part of this thesis to give a better overview on what I believe are necessary steps to be taken to reach that goal.

I have collected considerable and robust evidence, that there is a strong relationship between ecosystem functioning and sustainable human well-being. Biodiversity is key in the provision of the most basic prerequisites for human survival on this planet, today and into the future. It is also a necessary attribute of natural systems that provide aesthetic, moral and inspirational information to a nature-distant society. Especially to children and young adults.

In the face of a rapidly changing environment, prone to dramatic alterations, affecting coupled human-environmental systems in a significant, but largely unpredictable way, the central role of biodiversity in maintaining resilience becomes even more evident. While considering the huge amount of uncertainties that we face when trying to predict the trajectories of global change into the future, we must work on multi-faceted management strategies to ensure that our planet remains a nurturing environment for human endeavors and cultural evolution. Even if science needs to progress much further to get a hold of the complexity that surrounds the importance of biodiversity in complex-adaptive coupled human-environmental systems, the consensus is that we have to act, thorough and fast, to revert current trends of species loss and mitigate the problems it is causing and will cause.

Approaches to deal with this unpleasant situation must be flexible and reflexive and take into account the many different dimensions of the interdependent spheres of ecological, social and economic systems. Key ingredients of the recipe to successful conservation of biodiversity, as key to sustainable development, are:

1. Testing new approaches to manage complex-adaptive systems (CAS)
2. Fostering education and awareness
3. Valuing biodiversity in a framework broader than standard economic theory
4. Creating possibilities for participatory governance

7.1 Testing new approaches to manage CAS

Natural resource management is clearly in a crisis. Oceans are severely overfished, tropical forests are being cut down at huge rates, water supplies are getting scarcer by the minute, species are being lost at unprecedented speed, huge areas of productive land face erosion and degradation. At the same time human pressure on the environment is getting bigger. Population is still growing and demand for natural resources for consumption is sky-rocketing parallel to enhanced levels of well-fare around the planet, causing wide-spread pollution of land, water and air, climate change, shortages in supply of oil and industrial minerals, and alterations in biogeochemical cycles through anthropogenic manipulation. This situation is expected to make things even worse by using up resources in stock and thereby constraining future options. It is clear that we have to change the way we treat the environment now to avoid the 'perfect storm' for which the global stage seems to be readily set.

In doing so management approaches that take into account the complex-adaptive, evolutionary nature of coupled human-environmental systems, have great potential. We must acknowledge the dynamic behavior of such systems and the existence of surprises to be able to deal with them. We must also go beyond traditional management schemes that do not take into account the multiplicity of entities and actors involved in CAS or the different scales and speeds at which processes in CAS take place. From gene to biome and from seconds to millenia, holistic management tries to connect the levels and actors and aims to ensure resilient provision of goods and services in a changing environment. Theories and ideas in literature are numerous, and fascinating 'thinking-tools', like the concepts of adaptive cycles and panarchies, can help to guide management on different levels and in different contexts. It is very important that we move away from the hope for a panacea and rely on the ability of a scientifically very well informed, highly technologically advanced, and hopefully enlightened global society, to tinker multiple solutions, consisting of chumps of existing knowledge together with creative innovations on all different levels of society and culture. Making mistakes and learning from them will be inevitable. Making them now, with enough time and resources still in stock to apply what we have learned, is mandatory in a fast and globalized society, which is not only part of the problem but also bears a huge potential of change in the way we co-exist with nature.

7.2 Fostering education and awareness

Understanding the nature of a problem is the first step towards the solution. We have seen that knowledge about biodiversity-related issues is often constricted to a few highly informed scientists and professionals whereas the general public is largely unaware of the magnitude and causes of the biodiversity crisis we are currently facing. Nevertheless societal concern and people's will to act can easily be sparked, if certain basic facts are transported to the public and a minimum level of understanding is reached. It has been convincingly shown that humans have always relied on heuristic conceptualizations of the complexity that is inherent to nature. Therefore the information provided must neither be complete nor perfect. But it must include the basic ideas and, very importantly, it must be provided in the first place. Whether this happens through formal or informal channels does not make a crucial difference, as long as the way of provision gives people the chance to form their own opinions in an unrestricted way. Ideally such a process includes the chance for people to express their take on the matter in a discursive way. Discussions can trigger a social learning process that evolves, spreads and reaches all stakeholders.

7.3 Valuing biodiversity in a framework broader than standard economic theory

People are only willing to contribute their power, mind and money to something they value. Although value is often expressed in monetary terms and the universal usage of money as an indicator of value is undeniable, it is not sufficient to simply put a price on nature, even if that was possible.

Nature's assets like biodiversity are worth more than what can be expressed in Dollars or Euros. They encompass a variety of economic, social, moral, ethical, cultural and spiritual values that can hardly be expressed in markets. Not to mention that the value of a functioning ecosystem is essentially infinite as it supports our very existence and cannot possibly be substituted with technology.

Nevertheless a monetary indicator can help to give clear indications to stakeholders and decision-makers about what is at stake, because these numbers are easily understandable even if the familiarity with the underlying ecosystem dynamics is barely existent. Still such measures must be taken into account with caution. It is for example problematic at least to put a discount rate on ecosystem goods and services, and it is hard to incorporate future uncertainty and insurance against the crossing of thresholds towards undesired states into a single amount of money. If the ecological problems with valuation were not enough there is still the sociological, psychological and cultural side to it, complicating things further.

People are not always well informed about what they are asked to value. They often do not know which is the best option to choose out of many. They may very well not respond in a logical way to a question of value, because we share an innate relationship with nature, that makes it feel unethical to make economic judgments about it.

We must move beyond one-of-a-kind optimal solutions and accept that monetary valuation can only be a part, although an essential part, of a broader framework expressing and transporting the total value of ecosystems.

An important step to move on in this quest is to get rid of mono-disciplinary definitions of the human actor in science. Such reductions of the complex, often contradictory , intuitive, creative, egoistic and altruistic, logical and illogical behavior of human beings, lead to detrimental misconceptions, not only when management or policy rely on them but also when such explanatory models are taught at schools or universities, educating people to actually behave in such ways.

7.4 Creating possibilities for participatory governance

It is necessary to design platforms where scientists, politicians, managers, and lay people can interact and find solutions together, when the discussion is about common goods, like biodiversity. This should be possible from local to regional up to global scales. The decision process must be transparent and fair and expressed votes or preferences must not be based on manipulation, but fostered and guided by truthful information and open discussion. In that way everybody gets the chance to form his or her own opinion and share it with others to reap mutual benefits. The role of the government (agency) and experts is solely to inform and guide decisions as well as to facilitate the exchange between stakeholders. Of course they have a say in the decision but they are not allowed to decide on their own. This requires some drastic changes in our current political system. The job won't be easy. Matters of geopolitical and inter-generational fairness must be considered and a highly diverse set of stakeholders, all having individual agendas, must be brought together, coached and mediated throughout the process to ensure the equality of different interests within the group.

In a time of advanced communication channels, the infrastructure for participatory governance is already in place, waiting to be used by those who put the well-being of society over the dreaded loss of institutionalized power. People want to make a difference, a contribution that benefits everybody in society as well as future generations. It is just a matter of giving them the opportunity, information and space to do so. To parts this responsibility lies in the hands of the scientists, who must urgently move out of the 'ivory tower', across disciplinary borders and into the 'land of the lay', equipped with their best theories and methods and without fear of discourse and discovery, keeping an always open mind.

8 Research Question and Hypothesis

How do students understand the value of biodiversity and what role does educational background play in the ranking of possible ways of mitigating biodiversity loss and in willingness to get active personally?

1. Hypothesis: Students lack awareness of the importance of biodiversity due to gaps in knowledge.

2. Hypothesis: Students have different knowledge of biodiversity issues, depending on their educational background.

3. Hypothesis: Students have different conceptions of the value of biodiversity, depending on their educational background.

4. Hypothesis: Students favor different management strategies for biodiversity conservation, depending on their educational background.

9 Materials and Methods

An online questionnaire study, following the rules and advices of Diekmann (2007), was conducted with students from different faculties at the different universities in Vienna.

9.1 Structure of the questionnaire

The questionnaire was structured around a number of topical clusters. In chronological order: knowledge and awareness of biodiversity loss, personal and societal valuation of biodiversity in economic as well as in moral terms, individual preference for different management schemes, additional questions about inter- and transdisciplinarity, affiliation with environmental NGOs and educational background (university only), as well as demographic questions concerning gender, age and childhood environment. The full questionnaire can be found in the appendix.

The single questions were composed in an easily understandable way, the prior expected level of knowledge about the topic was Matura-level. The type of answer possibilities (multiple choice, scaled answers, open questions, etc.) was chosen carefully to obtain the data necessary to answer the research question and test the hypothesis.

9.2 Choice of study participants and distribution of the questionnaire

To asses the role of different educational backgrounds in the process of valuing biodiversity issues, it was necessary to choose a sample that represents different university programs. The choice of which departments or universities to include depended on one hand on the research question and on the other hand on logistical constraints. Students of the biological sciences and economics constituted the minimum requirement.

A pre-test for validity of the questionnaire was performed with 12 random students who were given the questionnaire manually and were asked about the formulation and clarity of the questions after filling it out. The mean time for answering all 29 questions was about seven minutes. No major changes were made in the questionnaire following validation.

Consequently the questionnaire was designed in electronic fashion on a payment-free website, named *studentenforschung.de*.

Because the questionnaire was distributed in an electronic format only and because it turned out to be difficult to reach enough students of the two focus groups, the sample was expanded. The first step was to promote the questionnaire in social networks and different university-related fora, affiliated with the studies of biology (Univ. Vienna), economics (WU Vienna), sociology , political science (Univ. Vienna), cultural and social anthropology (Univ. Vienna), and environmental science (BOKU Vienna). Due to obvious reasons the return rate could not be exactly determined in that case, because it cannot be said how many respondents from which forum answered the questionnaire in what stage (early or late) of the distribution over the whole time of the study. In any case the return rate was not high enough, so the questionnaire was also sent out via email to students who voluntarily disclosed their contact information in the u:net directory, which is available to open access on the homepage of the University of Vienna. Unfortunately, in that case, it was not possible to determine more than the gender of participants before administering the questionnaire, which lead to the sample being more diverse in educational backgrounds.

9.3 Data management

Data were collected and provided automatically in Excel output format. For statistical analysis the data were transformed into dBASE format to make successful import into SPSS possible. All participants were treaded anonymously.

Furthermore a new variable was created to pool the different studies into four groups: a natural science group (biology, physics, geography, medicine, ecology, human ecology, social ecology, etc.), a humanities group (arts, languages, sociology, psychology, law, political science, etc.), an economics group (business management, international business management, national and international economics, ecological economics, etc.), and a technical science group (computer studies, architecture, etc.). The formation of the groups was arbitrary. Difficult cases (for example when one respondent named two studies) were categorized into the group that best seemed fit. The procedure was inevitable to obtain group-numbers high enough to perform meaningful statistical analysis.

9.4 Statistical analysis

All statistical analysis of the data were realized with the help of IBM SPSS Statistics 20.

9.4.1 Structure of the sample

To get an overview of the whole sample, descriptive analysis were performed about the stratification of the sample in terms of educational background, gender and age. In the process the technical sciences group was integrated into the natural science group, because it only comprised 9 respondents (2.1% of all respondents). All further statistical procedures were performed with the resulting three groups.

9.4.2 Testing the hypothesis

In the first step the whole sample was analyzed, according to the topical clusters mentioned in section 9.1, to test for the validity of hypothesis 1 (see section 8), and to get a reference set to compare with the results in the different groups.

The second step was to uncover whether answers given to the questions depended on the affiliation with a certain group of studies, and/or other factors, like gender and to perform inter-group comparisons to show differences/similarities between the groups of studies. These analysis were used to test for hypothesis 2-4 (see section 8). This was achieved with the help of Chi-square tests.

10 Results

The final number of filled out questionnaires returned was 437. The approximate return rate for the questionnaires administered via the u:net directory, which contributed to more than half of the sample (about 237), was about 1 out of 10 (the questionnaire was sent to 2471 students). In the following, frequencies include missing values, which are not shown.

10.1 Descriptive analysis of the whole sample

The sample consisted of 69.1% female and 30.4% male respondents. The mean age of the respondents was 25.97 years with a standard deviation of 5.73 years. The median of the time studied in the sample was 8 semesters. On a five-stage scale (from 1 ‘heavily influenced’ to 5 ‘did not influence at all’) about whether students thought that their study subject influenced the answers given in the questionnaire, 48% of the respondents either answered with 1 or 2, 30.9% answered with either 4 or 5.

27.5% of the respondents stated that they are a member of an environmental organization or regularly support an environmental organization financially. About half of the respondents grew up in an urban environment (48.1%) and half in a rural environment (50.6%). 88.8% of respondents had come across the term ‘interdisciplinarity’ and 52.4% across the term ‘transdisciplinarity’ in connection to scientific work. 50.8% stated that they had already participated in interdisciplinary seminars or projects. 85.1% of the respondents believed, that cooperation between economists and ecologists helps to mitigate biodiversity loss.

10.1.1 Knowledge of biodiversity

Of all respondents 80.1% had already heard of the term 'biodiversity', 91% ticked the most adequate definition of biodiversity ('Biodiversity is the whole diversity of animal and plant species and ecosystems on this planet and the genetic information contained in them') and 39.2% thought that biodiversity is 'a basis for important ecosystem functions'. They also believed that 'loss of life-supporting ecosystem functions' was one of the main dangers of biodiversity loss, 88.9% ticked that answer. Another concern was 'the loss of genetic resources that could be of importance in the future', which was named by 66.4% of the respondents. 55.3% believed that biodiversity loss and climate change are problems of similar magnitude, half of the remaining respondents named biodiversity loss the bigger problem, half named climate change. Concerning the magnitude of species extinction until the year 2050, 63.5% of the respondents believed that it will lie between 10% and 30% of all currently living animal and plant species.

10.1.2 Feelings concerning biodiversity loss

On a five-stage scale (from 1 'very upset' to 5 'not upset') students were on average considerably upset when they heard of the extinction of a species (69.1% answered with 1 or 2). They also strongly believed that all species must be protected (95.7%). Although 69.4% believed that they could personally contribute to the conservation of biodiversity, 40.9% of those students did not know how to make a contribution. 40.4% of all respondents even stated that they feel 'helpless' in the face of biodiversity loss. Still 69.3% of the whole sample would be willing to spend between 0% and 5% of their monthly income to protect an animal or plant species. 56.4% of the students stated that they are environmentally aware and try to include that into their daily lives.

10.1.3 Valuing biodiversity

To highlight which kind of value (aesthetic, economic, moral, ecological-functional) students give to ecosystems and biodiversity, simple diagrams provide a good help. Aesthetic and economic values showed similar patterns of perceived importance (median = 2, on a five-stage scale from 1 = 'fits perfectly' to 5 = 'does not fit at all'). Moral value seemed to be of little bit higher importance to students (median = 2), and ecological-functional value

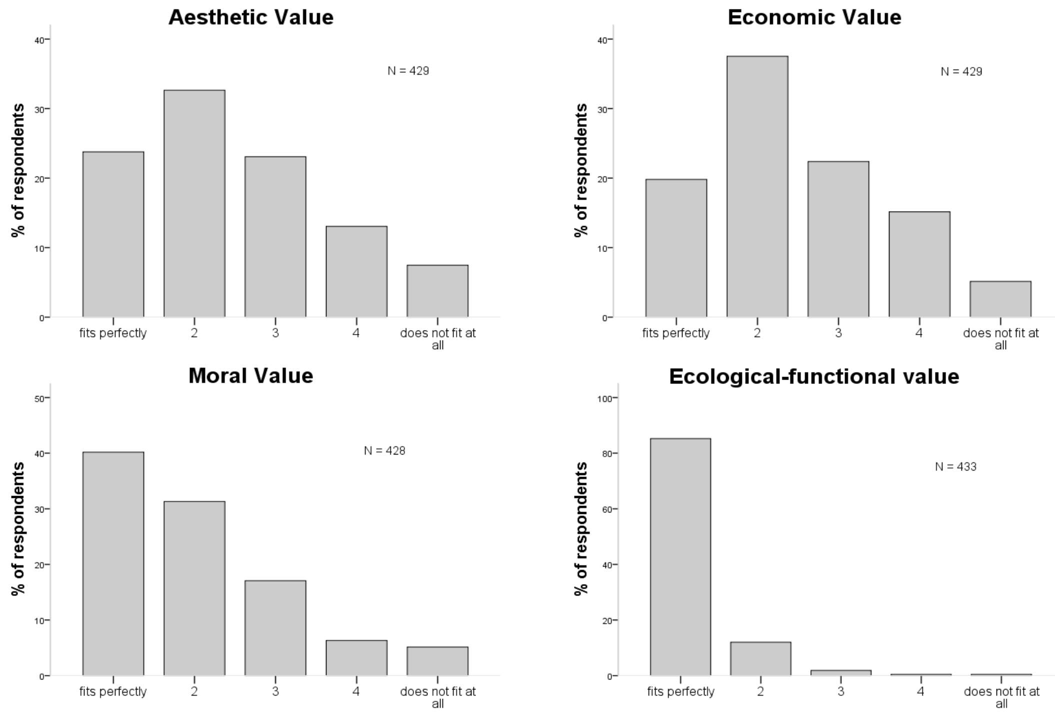

Figure 4: Different conceptions of the value of biodiversity

of major importance (median = 1). Please note the differences in scaling of the y-axis in figure 4.

77.6% of the respondents believed that nature should not be traded as a good on markets and 43.2% thought that it is important to express the value of species and ecosystems in monetary terms to raise awareness. 68.6% of the students believed that the monetary value of all species and ecosystems taken together lies in the range of trillion Euros per year.

10.1.4 Management options

Answers to the question about what students believed was the most effective way to protect biodiversity were pretty uniform in the categories: 'expand protected areas (without human influence)', 'change consumption patterns', and 'raise public awareness'. Between 80% and 90% of all respondents ticked those answers, the highest support (88.2%) was found for the last category. Only 44% ticked 'spend more money on the protection of the environment' and 6% ticked 'biodiversity regulates itself and does not need to be protected actively'.

The highest percentage of the respondents (96.1%) believed that experts (scientist, managers of protected areas) should design strategies for the protection of species. For the other 3 answers (the government, the local people, an international NGO) support ranged between 40% and 60%.

Concerning the support for different management strategies, between 60% and 80% of the students ticked the answers: 'experts design management strategies together with NGOs and governments'; 'public knowledge is fostered through education in schools, universities, museums, zoo, etc.'; and 'local initiatives are started were the local people are responsible for protecting local biodiversity'. The highest support (82.1%) was found for the second category. Only 17.4% of the respondents ticked the answer: 'biodiversity is tagged with monetary value, products arise that are profitable, markets regulate the protection of biodiversity'.

10.2 Stratified analysis

184 (43.4%) of the respondents were assigned to the natural science group, 180 (42.5%) to the humanities group, and 60 (14.1%) to the economics group. Missing values are excluded.

The results of the descriptive analysis divided into groups can be seen in figure 5. The share of male respondents was considerably higher in the economics group. Age, semesters studied, and childhood environment were pretty similar across the groups. The perceived influence of the subjects studied was highest in the natural science group. The share of respondents who had heard of the terms 'interdisciplinarity' and 'transdisciplinarity' was highest in the humanities groups, but in all groups approximately half of the students had already participated in interdisciplinary seminars or projects. Students from the economics group were less active in supporting an environmental organization, than students from the natural science group. Students from the humanities ranked in the middle. All groups showed high levels of support for cooperation between ecologists and economists in conserving biodiversity.

	Natural Science	Humanities	Economics
Female respondents Male respondents	130 (70.7%) 54 (29.3%)	136 (76%) 43 (24%)	29 (48.3%) 31 (51.7%)
Age (mean)	25.14 years (SD = 4.8)	26.77 years (SD = 6.51)	26.31 years (SD = 5.81)
Semesters studied (median + quartiles 25%, 75%)	8 (4 – 10)	9 (5 – 11)	8 (4 – 10)
Childhood environment	Urban: 90 (49.5%) Rural: 92 (50.5%)	Urban: 78 (43.8%) Rural: 100 (56.2%)	Urban: 35 (58.3%) Rural: 25 (41.7%)
Perceived influence of study (median + quartiles 25%, 75%)	2 (1 – 3)	4 (2 – 5)	3 (2 – 3)
Knowledge interdisciplinarity	Yes: 161 (89.4%) No: 19 (10.6%)	Yes: 168 (93.3%) No: 12 (6.7%)	Yes: 49 (81.7%) No: 11 (18.3%)
Interdisciplinary experience	Yes: 96 (52.5%) No: 87 (47.5%)	Yes: 88 (49.2%) No: 91 (50.8%)	Yes: 31 (53.4%) No: 27 (46.6%)
Knowledge transdisciplinarity	Yes: 89 (48.9%) No: 93 (51.1%)	Yes: 109 (61.2%) No: 69 (38.8%)	Yes: 24 (41.4%) No: 34 (58.6%)
Member/Supporter of environmental organization	Yes: 62 (34.6%) No: 117 (65.4%)	Yes: 44 (24.6%) No: 135 (75.4%)	Yes: 11 (18.6%) No: 48 (81.4%)
Cooperation Economists – Ecologists	Yes: 155 (85.2%) No: 27 (14.8%)	Yes: 155 (87.6%) No: 22 (12.4%)	Yes: 53 (89.8%) No: 6 (10.2%)

Figure 5: Demographic and additional information in groups

10.2.1 Knowledge of biodiversity

A significant dependency between study group and knowledge of the term 'biodiversity' was observed. The highest amount of knowledge of the term was found in the natural science group. Whether students ticked the most adequate definition of biodiversity was also significantly dependent on study group, in the humanities group the lowest number of respondents ticked that answer. Further significant dependencies on the affiliation with a certain study group were found in the believe of students, that biodiversity loss may lead to the loss of genetic resources, which could have been important for the future. A higher share of students from the natural science group had that concern. Students from the natural science group also gave overall higher estimations of species extinctions until the year 2050, in this question a significant dependency on affiliation with study groups was observed as well. Natural science students perceived biodiversity loss as a greater problem than climate change, students from the humanities and economics group believed it was the other way around. Although there was also found a significant p-value in this category, approximately half of the students from all groups stated that both problems are of the same magnitude. For a summary of the results see figure 6.

10.2.2 Feelings concerning biodiversity loss

Feelings concerning the loss of biodiversity were overall pretty similar in the three groups. Although students from the economics group seemed to feel less upset when they heard of the extinction of a species, and a higher percentage in that group seemed to feel indifferent to the problem of biodiversity loss.

Significant dependency on affiliation with a study group was found in the question that concerned whether students believed that they could personally contribute to the conservation of biodiversity, less students of the natural science though so. Further the willingness to pay a certain percentage of one's monthly income was also significantly dependent on affiliation with study groups. Results are depicted in figure 7.

10.2.3 Valuing biodiversity

The different categories of value of biodiversity appealed to the three groups in similar ways, with the exception of aesthetic value, which showed a significant dependency on affiliation with study groups. Students from the natural

	Natural Science	Humanities	Economics	P - value
"Biodiversity" known	Yes: 179 (97.3%) No: 5 (2.7%)	Yes: 120 (67.8%) No: 57 (32.2%)	Yes: 42 (70%) No: 18 (30%)	< 0.001*
Definitions of biodiversity A: most adequate definition B: basis for ES functions	A: 174 (94.6%) B: 75 (40.8%)	A: 153 (85%) B: 68 (37.8%)	A: 55 (91.7%) B: 22 (36.7%)	0.009* 0.783
Threats of biodiversity loss A: loss of function B: loss of genetic potential	A: 170 (92.4%) B: 133 (72.3%)	A: 153 (85%) B: 108 (60%)	A: 52 (86.7%) B: 39 (65%)	0.079 0.046*
Biodiversity loss vs. Climate change	BL: 51 (27.7%) CC: 28 (15.2%) equal: 105 (57.1%)	BL: 33 (18.4%) CC: 49 (27.4%) equal: 97 (54.2%)	BL: 13 (21.7%) CC: 19 (31.7%) equal: 28 (46.7%)	0.013*
Magnitude of species extinction A: 0.1 – 10% B: 10 – 30%	A: 56 (30.7%) B: 126 (69.3%)	A: 72 (40.7%) B: 105 (59.3%)	A: 25 (42.4%) B: 34 (57.6%)	0.021*

Figure 6: Differences in knowledge of biodiversity in groups

	Natural Science	Humanities	Economics	P - value
Which species to protect? A: all	A: 173 (94%)	A: 164 (91.1%)	A: 53 (88.3%)	0.316
Feelings - extinction of a species A: 1 (very upset) or 2 B: 4 or 5 (not upset at all)	A: 136 (73.9%) B: 11 (5.9%)	A: 127 (70.9%) B: 19 (10.6%)	A: 31 (53.5%) B: 5 (8.6%)	0.052
Feelings - biodiversity loss A: helpless B: don't know what to do C: environmentally aware D: indifferent	A: 78 (42.4%) B: 77 (41.8%) C: 112 (60.9%) D: 8 (4.3%)	A: 70 (38.9%) B: 74 (41.1%) C: 95 (52.8%) D: 15 (8.3%)	A: 23 (38.3%) B: 16 (26.7%) C: 30 (50%) D: 8 (13.3%)	0.748 0.093 0.182 0.053
Personal contribution to biodiversity conservation possible	Yes: 144 (76.1%) No: 44 (23.9%)	Yes: 115 (64.2%) No: 64 (35.8%)	Yes: 37 (64.9%) No: 20 (35.1%)	0.036*
Willingness to spend, of monthly income A: 0% B: 0 – 5% C: > 5%	A: 20 (10.9%) B: 132 (71.7%) C: 32 (17.4%)	A: 34 (19%) B: 127 (70.9%) C: 18 (10.1%)	A: 10 (17.2%) B: 38 (65.5%) C: 10 (17.3%)	0.018*

Figure 7: Differences in feelings concerning biodiversity loss in groups

science group attributed more aesthetic value to biodiversity than students from the other two groups. That nature should not be treated as a commodity, but that it is still somewhat important to express the value of species in monetary terms to raise awareness, these perceptions were not different between the groups. Students from the humanities gave lower estimates of the total value of all ecosystems and species. Answers to that questions showed a significant dependency on affiliation with study groups. See figure 8 for results.

10.2.4 Management options

Support for different management options in most categories was similar between the three groups. Still a significant dependency on study group was found in the categories: experts should design strategies for species conservation, and biodiversity is tagged with monetary value. A lower share of students from the economics group, compared to the other groups, thought, that strategies should be designed by experts. A lower share of students from the natural science group showed support for the 'price tag' management strategy. Results can be found in figure 9.

10.2.5 Gender effects

Some significant dependencies of answers to the gender of the respondents were observed, see figure 10. Female participants were more upset when they heard about the extinction of a species, a higher percentage of women felt helpless in face of the biodiversity loss problem. Male respondents on the other hand felt more indifferent to the problem. A higher percentage of men stated that nature is a commodity that could be traded on markets. Women attributed higher levels of aesthetic value to biodiversity than men, they also favored management strategies that involved raising public awareness more than men. A higher percentage of male participants supported the 'price tag' method to manage biodiversity.

	Natural Science	Humanities	Economics	P - value
Aesthetic value A: 1 (fits perfectly) or 2 B: 4 or 5 (does not fit at all)	A: 125 (68.7%) B: 23 (12.6%)	A: 82 (46.3%) B: 45 (25.4%)	A: 30 (50.8%) B: 18 (30.5%)	0.001*
Economic value A: 1 (fits perfectly) or 2 B: 4 or 5 (does not fit at all)	A: 110 (60.5%) B: 42 (23%)	A: 100 (56.5%) B: 35 (19.7%)	A: 33 (55.9%) B: 8 (13.6%)	0.46
Moral value A: 1 (fits perfectly) or 2 B: 4 or 5 (does not fit at all)	A: 122 (67.4%) B: 24 (13.2%)	A: 134 (75.7%) B: 20 (11.3%)	A: 35 (76.3%) B: 3 (5.1%)	0.141
Ecological – functional value A: 1 (fits perfectly) or 2 B: 4 or 5 (does not fit at all)	A: 180 (97.8%) B: 2 (1%)	A: 176 (98.4%) B: 0 (0%)	A: 54 (91.6%) B: 2 (3.4%)	0.161
Nature a commodity	Yes: 30 (16.6%) No: 151 (83.4%)	Yes: 44 (24.5%) No: 134 (75.3%)	Yes: 13 (22.4%) No: 45 (77.6%)	0.157
Awareness through monetary valuation	Yes: 71 (39.2%) No: 110 (60.8%)	Yes: 82 (45.8%) No: 97 (54.2%)	Yes: 32 (53.3%) No: 28 (46.7%)	0.133
Total value of ecosystems per year A: millions B: billions C: trillions	A: 2 (1.1%) B: 38 (21%) C: 141 (77.9%)	A: 15 (8.8%) B: 48 (28.1%) C: 106 (62%)	A: 1 (1.7%) B: 14 (24.1%) C: 43 (74.1%)	0.002*

Figure 8: Differences in valuing biodiversity in groups

	Natural Science	Humanities	Economics	P - value
Best way to conserve biodiversity A: expand protected areas B: change consumption patterns C: spend more money on conservation D: raise public awareness	A: 150 (81.5%) B: 159 (86.4%) C: 86 (46.7%) D: 164 (89.1%)	A: 139 (77.2%) B: 149 (82.8%) C: 74 (41.1%) D: 159 (88.3%)	A: 46 (76.7%) B: 47 (78.3%) C: 26 (43.3%) D: 52 (86.7%)	0.536 0.305 0.555 0.873
Who should design strategies for protection of species? A: experts B: government C: local people D: international NGO	A: 180 (97.8%) B: 74 (40.2%) C: 98 (53.3%) D: 107 (58.2%)	A: 173 (96.1%) B: 78 (43.3%) C: 97 (53.9%) D: 116 (64.4%)	A: 53 (88.3%) B: 24 (45%) C: 28 (46.7%) D: 35 (58.3)	0.006* 0.747 0.607 0.428
Management strategies to conserve biodiversity A: experts + government + NGOs B: price tag C: public awareness D: local initiatives	A: 143 (77.7%) B: 20 (10.9%) C: 158 (85.9%) D: 123 (66.8%)	A: 136 (75.6%) B: 40 (22.2%) C: 141 (78.3%) D: 109 (60.6%)	A: 41 (68.3%) B: 14 (23.3%) C: 46 (76.7%) D: 36 (60%)	0.341 0.007* 0.109 0.395

Figure 9: Support for different biodiversity-management options in groups

	Female	Male	P - value
Feelings - extinction of a species A: 1 (very upset) or 2 B: 4 or 5 (not upset at all)	A: 225 (75%) B: 13 (4.3%)	A: 75 (57.7%) B: 22 (17%)	<0.001
Nature a commodity	Yes: 52 (17.5%) No: 245 (82.5%)	Yes: 36 (28.1%) No: 92 (71.9%)	0.018
Feelings - biodiversity loss A: helpless B: don't know what to do C: environmentally aware D: indifferent	B: 140 (46.4%) D: 15 (5%)	B: 32 (24.2%) D: 16 (12.1%)	<0.001 0.014
Aesthetic value A: 1 (fits perfectly) or 2 B: 4 or 5 (does not fit at all)	A: 158 (53.2%) B: 66 (22.2%)	A: 82 (63.1%) B: 22 (17%)	0.051
Best way to conserve biodiversity A: expand protected areas B: change consumption patterns C: spend more money on conservation D: raise public awareness	D: 278 (92.1%)	D: 104 (78.8%)	<0.001
Management strategies to conserve biodiversity A: experts + government + NGOs B: price tag C: public awareness D: local initiatives	B: 43 (14.2%) C: 260 (86.1%)	B: 32 (24.2%) C: 92 (69.7%)	0.013 <0.001

Figure 10: Significant gender differences

11 Discussion

Students in the sample had a differentiated view on the value of biodiversity. When presented with different management strategies to battle the loss of biodiversity, they did not believe that one single approach is superior to the others. But overall, economic methods, putting prices on biodiversity and ecosystems, found the least support. A possible explanation here could be, that biodiversity seems to be a topic that is emotionally loaded.

It is promising that most of the students in the sample showed a good deal of knowledge about the connection between biodiversity and ecosystem functioning. They saw ecological-functional value as the most important form of value of biodiversity. Still a considerable share of students had never heard of the term biodiversity and most of them underestimated the magnitude of species extinctions that are expected to happen in the near future.

It can be said that students are environmentally aware and care for the conservation of biodiversity, but the means to achieve this goal remained widely unknown and a feeling of helplessness prevailed.

Pooling studies in groups with similar disciplinary scope led to uncover some interesting differences in the ways students think about biodiversity. But whether this effects depend on education at the university, or the prior character of the students, can only be guessed here.

In addition to significant dependencies on the affiliation with a certain group of studies, some significant gender differences were also observed. It was not possible to test whether results obtained from the data also pertain to the whole student population, because no data for the size and structure of the whole population were present. In some cases results from other studies were used as a reference, in other cases results may indicate trends. Intergroup comparisons on that ground are of course limited in their explanatory force, but in situations of statistically significant differences, trends may be inferred.

Further biases may arise because of the grouping of the different studies. Some decisions of which study subject to put into which group were difficult. For example it was hard to define whether 'Cultural and Social Anthropology' would better fit into the natural sciences or the humanities group. It was finally put into the humanities group. For studies that are interdisciplinary in their design the grouping meant a reduction to one overarching scientific field. As the number of these 'complicated' decisions was not too high and the natural science and humanities groups are of similar size, that bias is expected to be rather of theoretical, than of statistical nature. Of course a bigger or more precisely stratified sample would improve the results.

Finally the high share of female respondents in the sample should be mentioned. This fact is not supposed to be the source for a bias because of a similar stratification of the whole student population at the University of Vienna (73.96 % female and 36.04 % male students enlisted in the 2011/12 semester). (StatistikAustria, 2012).

Participants in this study had a high level of formal education. Nevertheless almost 20% of the respondents had not heard of the term biodiversity before. This share, is comparable to the numbers found in similar studies (see section 6.3). Interestingly almost all students managed to choose the most adequate definition of biodiversity out of a set of four answers. Although only about 40% of the students named biodiversity a basis for important ecosystem functions, almost 90% feared the loss of such functions together with the loss of biodiversity. This asymmetry between perceived gains and losses indicates irrational human behavior, already discussed in section 6.4.

Students underestimated the magnitude of species extinction. About 40% of the sample expected it to only reach levels of a maximum of 10% of all currently living species until 2050. In comparison to what is expected in scientific circles this is a rather low estimate (see section 4.5).

Students expressed high levels of concern about extinction and protection of species. Functional redundancy of species or lack of economic and aesthetic value were not perceived as hindrances to conservation. Virtually all respondents stated that all species must be protected. The distribution of answers to that question was so much one-sided that it can be stated that respondents have lexicographic preferences (see section 6.2) when it comes to decide whether or not to protect certain species. It may also be related to innate positive tendencies towards nature (see section 6.4).

About half of the students in the sample rated themselves environmentally aware and approximately 70% believed that they could personally contribute to biodiversity conservation. But more than half of the students who believed that, stated that they did not know how to make a contribution. This shows that whereas support for protection of the environment and willingness to contribute are high, a lot of students felt overwhelmed by the task. This may be related to findings of wide but shallow support for biodiversity conservation (see section 6.3).

Respondents overall attributed high levels of different forms of value to biodiversity, but with overarching support for ecological-functional value. Interestingly moral value seemed to rank on second place amongst students in the sample. These findings deviate to some extend from the statement made in literature, that biodiversity will most likely be conserved due to intrinsic or utilitarian values (see section 4.6 , p. 20). Although moral value is related to intrinsic qualities of biodiversity and ecosystems, ecological-functional value cannot be fully categorized as utilitarian in the sense of economic theory. Preservation of the ecological-functional value of biodiversity may well lead to "obtain pleasure and avoid pain" (Screpanti and Zamagni (2010), p. 83), but it does not necessarily produce commodities that can be owned by individuals. It provides regulatory services that are out of the reach of markets. As utilitarian value is per definition connected to property (Screpanti and Zamagni (2010), p. 84), ecological-functional value does not fully fit into this category. This is further supported by the fact that 77% of the students in the sample rejected the definition of nature as a commodity that could be traded in markets. The scope of the authors in section 4.6 lies on agriculture, which is of course a different perspective than the one of this study, but to describe the value given to biodiversity by the students in the sample, 'utilitarian' should be replaced by 'ecological-functional', to capture the real motivation to conserve biodiversity.

When asked about the total annual monetary value of all species and ecosystems taken together, the largest share of students in the sample gave estimates that range in the same height like those that were calculated by Costanza et al. (1997).

Considering the preferences for the different management options proposed in the questionnaire, students tended to favor differentiated approaches that consist of multiple strategies to cope with biodiversity loss. Interestingly they showed less support for financial aid mechanisms to protect biodiversity, and even less for regulation through markets. This is underlined by the fact that less than half of the students in the sample thought that it is important to express the value of species or ecosystems in monetary terms to raise awareness. Overall students in the sample seem to be in line with the multi-faceted approach of this thesis (see section 7), but there is a tendency to favor scientific, political and societal over economic measures. A strong support for expert-driven management was observed, although students believed that raising public awareness and fostering knowledge through formal and informal education are the best ways to protect biodiversity.

Hypothesis 1 is supported by the underestimation of the magnitude of species extinction and the still high amount of students who had never heard of the term biodiversity. But it is also evident that students can make the connection between biodiversity and ecosystem functioning and they show high levels of concern for biodiversity conservation and value it accordingly. It may be that students in the sample lack awareness of the economic valuation approach to conserving biodiversity, and therefore do not show much support for such a methodology. This is an understandable situation, because the approaches are still questioned in the scientific community and are relatively new. Active transportation of the topic to stakeholders may empower them to form opinions which are more differentiated than simple rejection.

Overall the three groups were similar in their structure, except for the disproportional high share of male respondents in the economics group. That students of the natural science group more strongly believed that their answers were influenced by their study subject, is not very surprising, because the topic of the questionnaire after all was an environmental issue.

Hypothesis 2 is supported by the higher share of natural science students that knew the term biodiversity and by the lower share of humanities students that chose the most adequate definition of biodiversity. Humanities and economics students considered the loss of genetic potential less threatening than natural science students. Interestingly in the natural science group more students thought that biodiversity loss was a bigger problem than climate change in the moment. Although most students in all three groups believed that both problems are of similar magnitude, this is a rather unexpected outcome, which stems probably from educational background rather than influence of the media, which in recent times was much more loaded with information about climate change. Finally economics and humanities students underestimated the projected rates of species extinction even more than students from the natural science group.

A significant dependency on affiliation with study groups was observed in the distribution of answers to all of these questions.

A higher percentage of humanities and economics students were not willing to pay anything for the conservation of a species and less students from these two groups believed, that they could personally contribute to the conservation of biodiversity. This may be because students from the humanities and economics group value biodiversity less than students of the natural sciences, but it could also stem from a high amount of helplessness in the face of biodiversity loss, which was observed as well.

Only aesthetic value showed considerable differences in the three groups. Natural science students attributed higher amounts of aesthetic value to biodiversity, for which I personally cannot find a logical explanation. It may well be that gender effects distort this result. Interestingly male respondents attribute higher levels of aesthetic value to biodiversity than female respondents.

Students from the humanities group gave lower estimates of the total value of species and ecosystems than the other two groups, which I also cannot explain properly. Overall the perceptions of the value of biodiversity are pretty uniform across the groups, therefore hypothesis 3 should be dismissed.

Only in two categories of the different management options significant dependencies on affiliation with study group were found. Students in the economics group showed less support, in comparison to the other two groups, for conservation strategies designed by experts, and natural science students showed less support for the 'price tag' method to conserve biodiversity than the other two groups. Whereas for the first result a reasonable explanation can only be guessed, the second result suggests that students from the natural science group have a tendency to oppose economic methods of valuation of biodiversity. Although there is a significant gender effect in this question as well (men have a more positive attitudes towards economic valuation than women), the fact that the economics and the humanities group show similar distributions of answers and only the natural science group falls out of line, supports the argumentation.

Support on this grounds is low for hypothesis 4. Overall the three study groups all favored multiple management approaches, therefore hypothesis 4 should also be dismissed.

It became obvious in the course of this work, that testing for the different levels of knowledge, conceptions, and feelings concerning biodiversity conservation, is a very sensitive matter. With such a complex and manifold topic it turned out to be hard to design questions that hit the core of what people think about the value of nature. It was especially challenging, because the normative horizon of the topic cannot easily be expressed in single or multiple choice questions. Interviews or group discussions could have served better in uncovering emotional ties with nature which seem to make a huge contribution to the opinions about biodiversity.

The questionnaire study on the other hand allowed for a big number of participants and helped to uncover some significant results in the comparisons of the different study groups, and some significant gender effects. These effects should be taken into consideration when we think about ways of how to convey the topic of the biodiversity crisis and the importance of conservation to these different groups of stakeholders.

Of course much more theoretical work must be done to unravel the whole complexity of the different conceptions of the value of biodiversity. Bigger sample sizes and more precisely stratified analysis could be a promising first step into this direction. But results from this study strongly suggest, that if management strategies were designed and put in place, in such a way that they incorporate the mix of approaches discussed throughout this thesis, they would find wide support in the student community.

Maybe it also needs more differentiated definitions about what biodiversity really is, or better what it means to us, because biodiversity goes even beyond all the forms of value discussed in this work. A philosophical discussion about the topic should take place to make the grounds on which further talk about utilitarian or intrinsic, economic or ecological forms of value can flourish. Philosophers of science (see for example Plutynski (2007)) make important and innovative, but often underestimated contributions to the understanding of the very nature we humans deal with the environment. Thinking about the tensions and dependencies that exist in this relationship, understanding little chunks and describing them, and bringing the different theories together, is one of the first steps on a surely stony, but necessary and rewarding way to a future as diverse as today.

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12 Appendix

12.1 Deutsche Zusammenfassung

Zahlreiche wissenschaftliche Ergebnisse, welche die wichtige Rolle von Biodiversität in der Erhaltung von Ökosystemfunktionen unterstreichen, wurden im Laufe der letzten Jahre publiziert. Biodiversität sichert die Bereitstellung von Ökosystemleistungen und -gütern die für das Überleben und Wohlbefinden der Menschheit unerlässlich sind. Obwohl weitere Studien nötig sind um die Mechanismen beschreiben zu können, die hinter den beobachteten Verbindungen zwischen Biodiversität und Wohlbefinden stehen, werden die Stimmen zu handeln lauter angesichts des Verlustes an Biodiversität, der heute annähernd so groß ist wie zur Zeit der fünf großen Aussterben in der Erdgeschichte. Zentrale Wichtigkeit bei der Verminderung der Auswirkungen dieser Krise und der Anpassung an ihre Folgen sind: interdisziplinäre Kommunikation zwischen Wissenschaftern und Politikern, Förderung von Wissen zu dem Thema innerhalb der Gesellschaft, und weitere Studien über den naturwissenschaftlichen Hintergrund. Eine methodische Auffassung von Wert und Inwertsetzung von Biodiversität ist eine wichtige Voraussetzung für diese Unterfangen und mögliche Managementszenarien. Meine Arbeit wird sich mit der Komplexität dieser Dimensionen von erfolgreichem Biodiversitätsschutz auseinandersetzen. Die empirischen Ergebnisse werden diesen multidimensionalen Zugang in verschiedenen Gruppen von StudentInnen hoffentlich reflektieren und eine Basis von Vorschlägen für erfolgreiches Management von Biodiversität und Ökosystemfunktionen legen.

12.2 Questionnaire

Willkommen bei meinem Fragebogen zum Thema Biodiversität/Artenvielfalt, im Rahmen meiner Diplomarbeit! Ich bin für jeden Beitrag sehr dankbar und bitte dich den Fragebogen vollständig auszufüllen.
Dauer: ca. 7 min

Anfangen

1.

Hast du schon einmal von dem Begriff "Biodiversität" gehört?

- ◯ Ja
- ◯ Nein

2.

Welche der folgenden Aussagen beschreiben den Begriff Biodiversität am besten? Biodiversität ist:
(Mehrfachantworten möglich)

- ☐ ... die gesamte Vielfalt an Tier- und Pflanzenarten und Ökosystemen auf diesem Planeten und die genetische Information die in diesen enthalten ist.
- ☐ ... das unterschiedliche Angebot von biologischen Nahrungsmitteln im Supermarkt.
- ☐ ... die Gesamtheit der verschiedenen Tier- und Pflanzenarten.
- ☐ ... die Grundlagen für wichtige Ökösystemfunktionen.

3.

Was ist deiner Meinung nach aktuell das größere Problem, Klimawandel oder Verlust von Artenvielfalt?

◯Klimawandel
◯Verlust von Artenvielfalt
◯beide Probleme sind gleich groß

4.

Welche der folgenden Gefahren würdest du mit dem Verlust an Biodiversität in Zusammenhang bringen?
(Mehrfachantworten möglich)

☐Verlust lebenswichtiger Ökosystemfunktionen
☐Umweltkatastrophen haben schwerwiegendere Auswirkungen
☐Hungersnöte
☐Verlust genetischer Ressourcen die in Zukunft wichtig werden könnten
☐keine der oben genannten

5.

Wieviel Prozent der heute lebenden Tier- und Pflanzenarten werden deiner Meinung nach wahrscheinlich bis 2050 ausgestorben sein?

◯0,1% - 1%
◯1% - 10%
◯10% - 20%
◯20% - 30%

6.

Wie fühlst du dich wenn du vom Aussterben einer Tierart erfährst?

sehr betroffen ◯ ◯ ◯ ◯ ◯ garnicht betroffen

7.

Wie fühlst du dich angesichts des Problems des Biodiversitäts - Verlustes?
(Mehrfachantworten möglich)

- ☐ Hilflos
- ☐ Gleichgültig
- ☐ Ich möchte etwas ändern weiß aber nicht wie
- ☐ Ich bin ein umweltbewusster Mensch und versuche das in meinem täglichen Leben umzusetzen
- ☐ Biodiversitäts - Verlust stellt kein Problem dar

8.

Glaubst du, dass du persönlich dazu beitragen kannst Biodiversität zu bewahren?

- ◯ Ja
- ◯ Nein

9.

Wieviel Prozent deines monatlichen Einkommens würdest du für den Schutz einer Tier- oder Pflanzenart ausgeben?

- ◯ 0%
- ◯ 0% - 5%
- ◯ 5% - 10%
- ◯ 10% - 20%

10.

Welche Art von Wert haben deiner Meinung nach Ökosysteme und Biodiversität?

	trifft genau zu				trifft garnicht zu
einen ästhetischen	◯	◯	◯	◯	◯
einen wirtschaftlichen	◯	◯	◯	◯	◯
einen moralischen	◯	◯	◯	◯	◯
einen ökologisch-funktionellen	◯	◯	◯	◯	◯

11.

Glaubst du, dass die Natur eine Ware ist die auf einem Markt gehandelt werden kann?

◯Ja
◯Nein

12.

Glaubst du ist es wichtig, dass Spezies und Ökosysteme in Geldwerten ausgedrückt werden sollen um ein Bewusstsein für sie zu schaffen?

◯Ja
◯Nein

13.

In welcher Höhe glaubst du liegt der ungefähre Geldwert aller Ökosysteme und Spezies zusammengenommen (pro Jahr)?

◯ in Hundertausenden Euro
◯ in Millionen Euro
◯ in Milliarden Euro
◯ in Billionen (=1000 Milliarden) Euro

14.

Wieviel ist deiner Meinung nach eine Tier/Pflanzenart monatlich wert?

15.

Was ist deiner Meinung nach der effektivste Weg Biodiversität zu bewahren?
(Mehrfachantworten möglich)

- [ ] geschütze Gebiete (ohne menschlichen Einfluss) vergrößern
- [ ] Konsumverhalten verändern
- [ ] mehr Gelder für Umweltschutz ausgeben (Steuern, Spenden)
- [ ] Aufklärung und Bewusstseinsschaffung in der Bevölkerung
- [ ] Biodiversität muss nicht aktiv bewahrt werden, bzw. reguliert sich selbst

16.

Wer sollte Pläne zum Artenschutz ausarbeiten?
(Mehrfachantworten möglich)

☐Experten (Wissenschafter, Naturschutzgebiete-Manager, o.ä.)
☐die Regierung
☐die ansässige Bevölkerung
☐eine internationale NGO (Greenpeace, WWF, o.ä.)

17.

Welche der folgenden Management-Strategien tragen deiner Meinung nach am meisten zum Schutz von Biodiversität bei?
(Mehrfachantworten möglich)

☐Experten arbeiten mit Regierungen und NGOs Pläne zum Umweltschutz aus
☐Biodiversität bekommt ein Preisschild, es entstehen Produkte die gewinnbringend sind, Märkte regulieren den Schutz von Biodiversität
☐Das Wissen innerhalb der Bevölkerung zum Thema Biodiversität wird durch Unterricht/Bildung in Schulen, Universitäten, Museen, Zoos, etc. gezielt gefördert
☐Lokale Initiativen werden angestoßen, die ansässige Bevölkerung trägt die Verantwortung für den Schutz der lokalen Biodiversität

18.

Glaubst du, dass Zusammenarbeit zwischen z.B. ÖkonomInnen und ÖkologInnen hilft den Verlust von Biodiversitäts zu mindern?

◯Ja
◯Nein

19.

Sind deiner Meinung nach manche Spezies eher zu schützen als andere?

☐alle Spezies müssen geschützt werden
☐von zwei Spezies die ähnliche Funktionen im Ökosystem erfüllen ist eine überflüssig

☐ nur jene Spezies die einen wirtschaftlichen Wert haben müssen geschützt werden
☐ nur ästhetisch wertvolle Spezies müssen geschützt werden

20.

Ist dir der Begriff "Interdisziplinarität" schon einmal in Verbindung mit wissenschaftlicher Arbeit begegnet?

◯ Ja
◯ Nein

21.

Ist dir der Begriff "Transdisziplinarität" schon einmal in Verbindung mit wissenschaftlicher Arbeit begegnet?

◯ Ja
◯ Nein

22.

Hast du schon in interdisziplinären Projekten, Seminaren etc. mitgearbeitet?

◯ Ja
◯ Nein

23.

Bist du Mitglied einer Umweltschutz-Organisation oder spendest du einer Umweltschutz-Organisation regelmäßig Geld?

◯Ja
◯Nein

24.

In welcher Umgebung bist du aufgewachsen?

◯urban oder städtisch
◯ländlich

25.

Wie sehr denkst du hat dein Studium die Beantwortung der Fragen beeinflusst?

sehr beeinflusst ◯ ◯ ◯ ◯ ◯ garnicht beeinflusst

26.

Welche Studienrichtung ist dein Hauptfach?

27.

Wieviele Semester studierst du schon?

28.

Dein Geschlecht?

◯weiblich
◯männlich

29.

Dein Alter?

Fertig!

Vielen Dank, dass du dir für die Umfrage Zeit genommen hast! :)

Einen schönen Tag noch!

Curriculum Vitae

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Geboren am 03.10.1986 in Wien, Österreichische Staatsbürgerschaft.

Praxiserfahrung

Dezember 2011 – Februar 2012	Praktikum am Institut für Soziale Ökologie der Fakultät für Interdisziplinäre Forschung und Fortbildung (IFF) der Universität Klagenfurt
März – Juli 2011	Teilnahme an der 'INEX Sustainability Challenge' mit dem Service Learning Projekt: "Dorfplatz statt Parkplatz" – Regionalentwicklung in der Gemeinde Sonntag Stein, Vorarlberg
Wintersemester 2010/11	Co-organisation der Veranstaltung "Let's Talk Green", auf der WU Wien; Präsentation nachhaltiger Unternehmen und Podiumsdiskussion mit u.a. Umweltminister Niki Berlakovich; im Rahmen der LV "GeKo: Sustainability Economics" von Prof. Sigrid Stagl
April – Dezember 2006	Grundausbildung in Laborarbeit, sowie Mitarbeit bei Verhaltensexperiment an Mäusen, Labor für Grundlagenforschung an der Univ. Klinik f. Kinder- und Jugendheilkunde Wien; im Rahmen des Zivildienstes

Ausbildung

Wintersemester 2005/6 – laufend	Diplomstudium der Biologie an der Universität Wien mit Schwerpunkt Ökologie und Spezialisierung in Humanökologie; laufende Diplomarbeit mit dem Titel: "Awareness of the value of Biodiversity: A questionnaire study with University students from different educational backgrounds", Abschluss vorausslichtlich im Oktober 2012
Juni 2005	AHS Matura mit ausgezeichnetem Erfolg, Öffentliches Gymnasium der Stiftung Theresianische Akademie, Wien

Weitere Kenntnisse	Englisch fließend in Sprache und Schrift, grundlegende Kenntnisse in Spanisch und Französisch
	Gute Computerkenntnisse in Office (PowerPoint, Excel, Word), grundlegende Kenntnisse in Microsoft Access und SPSS, Verwaltung von Literaturdatenbanken (JabRef,

	Refman), Textverarbeitung mit LaTex und Posterdesign
	Unbeschwerter Umgang mit sozialen Medien (Facebook, Twitter, Blogs etc.)
	Führerschein Klasse B
	Literatur, kreatives Schreiben, Gemüsegarten, Fußball

Publikationen

2012	Frischer, C., Grohs, M., Handschuh, S., Lang, J., MacLeod, M., Sarto-Jackson, I., et al. (in press). Review of Wimsatt (2007). Biological Theory, 6.
2008	Strain-dependent effects of cognitive enhancers in the mouse. Sunyer B, Patil S, Frischer C, Hoeger H, Lubec G. Amino Acids. 2008 Apr;34(3):485-95.
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