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Confronting and Coping with Uncertainty in Biodiversity Research and Praxis

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Abstract

This paper summarises discussions in a workshop entitled "exploring uncertainties in biodiversity science, policy and management". It draws together experiences gained by scientists and scholars when encountering and coping with different types of uncertainty in their work in the field of biodiversity protection. The discussion covers all main phases of scientific work: field work and data analysis; methodologies; setting goals for research projects, taking simultaneously into account the agency of scientists conducting the work; developing communication with policy-makers and society at large; and giving arguments for the societal relevance of the issues. The paper concludes with a plea for collaborative learning that would build upon close cooperation among specialists who have developed expertise in different fields in research, management and politics.

Keywords

Biodiversity science, biodiversity management, biodiversity policy, dimensions of uncertainty, governance of biodiversity, research practice, scientific agency, social deliberation, social learning, uncertainty

1. Introduction

Biodiversity is a multidimensional issue. When working with biodiversity, there are multiple sites of uncertainties involved at all stages from mundane steps of empirical field research to formulating political recommendations. However, uncertainty has usually been addressed from a narrow perspective (Haila and Henle 2014). "Exploring uncertainties in biodiversity science, policy and management" was the theme of a workshop held at the auspices of Helmholtz Centre for Environmental Research, UFZ, Leipzig, in November 2011. In this paper, we summarise issues that were taken up during the discussions.

The aim of the workshop was to establish a comprehensive agenda for assessing uncertainties in biodiversity praxis. We use the term 'biodiversity praxis' as a shorthand for all the activities supporting applied biodiversity conservation, including conducting research by collecting and analysing data, summarising and interpreting the results, drawing conclusions on conservation targets and formulating management guidelines and policy goals. All such tasks comprise decisions oriented toward the future. Formulating grounds for such decisions entails uncertainties.

We adopted a pragmatic focus: our goal was to produce an inventory of how natural and social scientists involved in biodiversity research have come across and coped with uncertainty in their working practice. The background of the workshop is described in more detail by Haila and Henle (2014) who also outline the pre-analytic starting points.

The workshop procedure was structured by short prepared presentations, most but not all of them with slides, invited from most of the participants with different background experience. The discussions were recorded and transcribed. This paper summarises main themes that were raised in the workshop, based on screening the transcripts (by YH) and a repeated editing process by the participants. As the paper is built on the points made by the participants during the workshop discussion, we use citations extracted and edited from the transcripts in the body of text. The speaker is indicated by his or her first and family names on the first occasions, and by the first name later on.

We adopted *semantic space* as a basic tool for drawing distinctions among specific types of uncertainties. A first step in analysing a semantic space is to define its dimensions (Haila and Henle 2014). This can be done by identifying practical and/or conceptual dimensions, which indicate the context of any specific type of uncertainty. We will get back to this point in the concluding section. In addition to the dimensions of the semantic space, two themes grew to serve as organising elements of the train of collective thought during the two-day discussion sessions:

[1] Of critical importance is the question asked and the type of data and model used to elaborate the case and identify what can potentially count as an answer. Our view of models as research tools is akin to the pragmatic perspective of Levins (1966) and Rosen (1991). A major issue relates to how the scope of the model is defined; Rosen (1991) used the term 'enclosure' to specify this step.

[2] The variety of practical roles that we, the participants, have had in our professional experience laid the ground for the discussions. This experience ranges from theoretical and empirical ecological and social science research, including the application of statistics and modelling, to science-policy dialogue, work in environmental administration, and hands-on biodiversity conservation.

In the following sections we take up main themes that were raised in the discussions of the workshops; the section titles are listed in Table 1. In the concluding section we give a suggestion on how to use the semantic space of uncertainties in biodiversity praxis as a tool that helps to specify what can be done to cope with uncertainty.

Table 1. The structure of the article.

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2. Starting Up

2.1 What is the question?

"Uncertainty becomes acute whenever we ask a question. If there is no question, there is no uncertainty. When we try to reduce uncertainty in one specific question we keep asking new questions, and more uncertainty will come out." (Joseph Tzanopoulos)

The question asked sets the stage. Alan Garfinkel used the notion of 'contrast space' to describe the set of alternatives among which the explanation has to be found for a specific problem. Contrast space makes explicit the context and precise sense of a research question (Garfinkel 1981; see Dyke 1988, 1993, Haila and Henle 2014). Answering a research question requires explanatory closure (Dyke 1988), and an appropriate contrast space indicates the boundaries of a closure.

With this requirement, we get to where strictly scientific questions end and other types of questions show up. The need to continuously ask new questions is an inherent part of the societal process of coping with changing conditions. New questions build upon existing knowledge. Closure, albeit a temporary one, is a method to bring together the elements deemed necessary for making sense of a question asked [see Sect. 5.1].

"One should try to narrow down the level of uncertainty by trying to ask a fairly concrete question. For me, this would mean in practical terms that if we ask new questions, we should not say older things are not important any more although that is often done in science. Nature conservation is perhaps sufficiently diverse in practice that we should retain a stronger memory." (Klaus Henle)

2.2 The basics of modelling

A basic epistemological strategy in empirical research is to explicate the context of the research question by constructing a model. The model delimits the research object by making visible the basic structure of the object being modelled so that necessary data can be collected, preferably experimentally although this is seldom feasible in field conditions, and calculations can be performed. A model abstracts and leaves out what is not considered essential (e.g., Levins 1966, Puccia and Levins 1985, Pielou 1977, Wimsatt 2007). For complex objects, such as biodiversity, decisions on what to include or exclude are seldom straightforward. When the decision based on the model is made, some uncertainty remains nevertheless. However, such uncertainties are often neglected when conducting research and communicating the results (e.g. Pe'er et al. 2013).

Several kinds of technical uncertainty are inherent in the modelling process and can be controlled to a certain extent by using systematic technical procedures. Regan et al. (2003) reviewed potential treatments of uncertainty in the case of population models.

Another type of uncertainty stems from deficient knowledge of the process under research, caused for instance by incomplete data sets.

“Systematic errors are measurement errors, and mainly caused by imperfect calibration of the measuring process that produces data. We can take into account random errors as standard deviations of our parameters. --- So, we may sometimes deal with a lack of accuracy, or poor quality of our data, but models are meant to work also with imprecise data.” (Yiannis Matsinos)

The nature of the research problem sets specific requirements on data quality.

“Incomplete data could be particularly detrimental when we deal with spatial modelling on different scales. --- It is important to focus on the quantitative aspects of assessment in modelling, to see how particular types of uncertainty affect model outputs in different scenario ranges, and to determine the accuracy of predictions that the model allows.” (Yiannis)

In addition, the modeller faces the dilemma that processes in nature may be inherently stochastic. Consequently, it is very difficult if not impossible to trace such inherent stochasticity and detach it from uncertainty stemming from inadequacy or lack of data. In real life, scientists have to cope with stochasticity because it is simply impossible to get enough data. Weather forecasts demonstrate this problem very concretely: The system is utterly sensitive to small differences in initial conditions, as the ”butterfly effect” parable of Edward Lorenz demonstrates (Lorenz 1993). But we have to recognize that stochasticity does not equal chaos.

“Can we handle the difference between deterministic and stochastic components of a setting? Sometimes we don’t know if something is stochastic because it is stochastic by nature, or only seems stochastic because we do not know enough. So for me this differentiation is superimposed on our lack of knowledge and our wish to assume that everything can be explained.” (Guy Pe’er)

2.3 Assessing errors

The distinction between type I error (rejecting a true null hypothesis) and type II error (accepting a false null hypothesis) is familiar, but drawing the borders requires care. In particular, the decision as to which one to emphasise is consequential. Statistics provides technical criteria for evaluating the reliability of the decision, but this is strictly conditional upon the formulation of the null hypothesis and the nature of the data [as to type III error, see Sect. 5.1].

Assessing errors is particularly relevant in biodiversity research studies that attempt to give advice for management. A manager may adopt a “rule of thumb” that cannot be validated by a formal statistical test because it functions only 70% of the time, say, due to variation in environmental or societal conditions.

"The determinism vs stochasticity balance is shifted toward the stochastic side when we move to societal issues, but in ecology at least, some processes can be regarded as reasonably deterministic. --- The question is, where to best place this balance. If you do the study only yourself, fine. You do the analysis and you know where you put the balance. But others may continue the methodological procedure and ignore the simplifying assumptions made when placing the balance. In statistics, we can witness an increasing move towards the use of information theoretical decision criteria, such as Akaike's Information Criterion for selecting among competing models. While the authors who introduced these concepts to biodiversity research outlined underlying assumptions and warned against careless interpretation of results [Anderson et al. 1994], when there is a lack of fit, most scientists applying such approaches nowadays do not care. I have shown with an example [Henle 2005] that this may lead to complete misunderstanding of relevant processes, and even to wrong management decisions." (Klaus)

2.4 Social-ecological models – a different species

Approaches to modelling in the social sphere are distinctly different from those adopted in the natural sciences. The differences are basically due to historical contingency and context specificity of processes in the social realm, but also to the fact that humans, as research objects, belong to the "interactive kind" (Hacking 1999). Research procedures certainly can affect target organisms, for instance when they are collected using traps, but only humans read research reports and may react to the conclusions by modifying their behaviour.

A fruitful possibility is to use socio-economic models in biodiversity research primarily for understanding and communication, and to refrain from making concrete predictions. Basically, the heuristics allowing generalizations are context specific in the socio-economic sphere. Objects modelled in the social sphere are hardly ever thought of as representations of a background population that would constitute a natural domain for generalizations. Rather, socio-economic models can be viewed as analogues that allow qualified generalisations over cases of a similar type (Haila and Dyke 2006; Haila and Loeber 2009).

"In social-ecological modelling, we use process-based simulation models, which include ecological and socio-economic components and feedbacks. We often use very simple models, we call them toy models, which are not aimed really for prediction, but rather for understanding, and as a tool of thinking and communication [Schlüter et al. 2012a]. We do our work together within an interdisciplinary team that includes ecological economists and has recently been augmented with social geographers. Qualitative and quantitative information on different levels, on different scales, can be used to reduce the uncertainty in model parameters and in model structure [cf. pattern-oriented modelling, Grimm et al. 2005, Grimm and Railsback 2012]. We also use inverse modelling methods for this purpose [cf. Refsgaard et al. 2007]. Furthermore, these models can explicitly consider the attitude towards uncertainty, or adopt strategies to deal with uncertainty of the natural resource user [Quaas et al. 2007, Müller et al. 2011].” (Birgit Müller)

For dealing with practical issues of natural resource management and conservation, participatory modelling has gained importance in the last decade (for a review see Voinov and Bousquet 2010). Here different groups of stakeholders participate in the modelling process. Different goals and problem framings of the stakeholders can be considered and made explicit to the researchers and other stakeholders right from the beginning (see also Schlüter et al. 2012b). The identification and characterisation of all sources of uncertainty can be made jointly (cf. Refsgaard et al. 2007 for an overview on uncertainty in the environmental modelling process). The collaborative learning process thus enhances problem understanding, inclusion of relevant factors and acceptance of the model outcomes.

A further approach – management strategy evaluation – may turn out to be promising for research on conservation issues in the future (Bunnefeld et al. 2011, Milner-Gulland 2011). In a virtual world, management scenarios can be evaluated for their robustness to uncertainty. This approach comes from fisheries science and includes stakeholders in the model. Exemplarily, a policy maker can set a fishing quota and determine the appropriate level of monitoring of catches by the fishermen. In the real world, full information is never available on fish catch, but rather it depends on the monitoring effort, which is associated with different levels of costs. In the virtual world, one can vary the knowledge of the system, so that different monitoring scenarios can be compared in terms of their cost/benefit ratios. This approach is closely related to the virtual ecologist approach (Zurell et al. 2010).

3. Research to support biodiversity praxis

The practical purpose of research is to increase understanding and explanatory capacity concerning the phenomenon of interest and, thus, to support reasonable recommendations on what should be done. This is a pragmatic dimension of biodiversity praxis. However, there is no smooth linear transition from the realm of research to the realm of policy across what is often depicted as the ”science–policy interface.” Rather, the transition implies choices between several interpretative frameworks concerning what aspects of the results to emphasise and what significance to give to uncertainty (Haila and Henle 2014).

3.1 Scientific agency

Scientists have had a major role in identifying biodiversity loss as a major problem, ever since the foundational BioDiversity meeting held in Washington DC in 1985 (Wilson and Peter 1988). Scientists initiated the discussion and constructed the arguments. Hence, the nature and credibility of scientific agency counts. The challenge for scientists is not only to produce knowledge. In fact, as Sarewitz (2004) argues, arguments derived from science alone may make environmental controversies worse by hiding from sight value conflicts that need to be articulated in order that social and political assessment of the nature of the problems is possible.

Value systems and ideological positions influence attitudes of scientists toward developing strategies for promoting the social relevance of what they do (Apostolopoulou and Pantis 2009). It is therefore advisable to take a pragmatic perspective as regards value assessments (following, for instance, Simon 1981 and Majone 1989): given alternative possibilities for action, values give guidance as to which one to choose. Furthermore, previous experience matters for the stabilization and articulation of values in specific situations.

In science, the type of successful work conducted previously acts as a point of reference, without which one cannot explain anything (Russell 1979). Similar to all humans, scientists are biased to some extent by their experience. Also, science is a historically and culturally dependent activity that extends a particular vision of reality through networks of power (Latour 1987, Hacking 1999). The way a question is posed and an answer is sought for determines at least partially the set of answers that can be obtained (Russell 1979, Gould 1980, Latour 1999).

"Scientists don't use only logical arguments. In an interview, a scientist gave me three advices: first, love the birds; second, love the birds; and third, love the birds. As Funtowicz and Ravetz [1990] point out, we as scientists have our stakes, and we have to make clear that we have our stakes. We want people to appreciate biodiversity." (Felix Rauschmayer)

Scientists may adopt alternative roles when going public. As Roger Pielke (2007) has pointed out, one possible role is to act as a knowledge broker by collecting different perspectives and presenting a balanced overview. Alternatively, a scientist may be an advocate who has a clear position in a particular controversial situation. This is a legitimate role as well (Orr 2004). Another role is that of "pure researcher".

"It's fine to have value components in your arguments, but one needs to be conscious about them. Then you can partially separate, let's say, logical arguments and value systems – although never completely. --- What is perhaps even more fundamental for politicians or any other stakeholders who deal with scientists is that scientists are often living in a system of their own theories and values in a broader sense. And scientists tend to adhere to their systems of theories and values. And it's often very difficult for them to change them." (Klaus)

3.2 To reduce, or to deal with uncertainty?

One of the obligations of scientists is to acknowledge the uncertainty pertaining to the practical mundane detail of the research process. This is all the more important as research on biodiversity and related issues has grown explosively during the last couple of decades (Henle et al. 2012). Science has acquired good methods and traditions to increase knowledge. In addition, however, we should acknowledge that uncertainty has different roles depending on the case at hand and the role we adopt.

"Does uncertainty have a varying role depending on the role we adopt? Do we have a different concept of uncertainty when acting as a lobbyist or advocate, as a knowledge broker, or when we act as, let's say, pure modellers? When being a lobbyist for butterflies in Israel, I would probably be much more easy-handed with uncertainties regarding the results as long as I can make a point that would move a policy maker to do something for the butterflies. But when I'm modelling, I'm much more careful to fix the confidence level to, say 0.05 or 0.04. When I'm facilitating workshops as a scientist, then perhaps I might use uncertainty primarily as a means to facilitate discussion." (Guy)

Scenarios are built-up images of possible futures with varying assumptions as to what kind of decisions are made (Settele et al. 2012, Spangenberg et al. 2012). Thus, scenarios offer potential for charting uncertainties depending on variation in initial conditions. When projecting index values toward the future, it is customary to use relatively simple indices to compress data on complex phenomena (Schubert 1991, Dziock et al. 2006) and assess with models the potential effect of various factors on the values; GDP (Gross Domestic Product) and HDI (Human Development Index) are examples in the socio-economic realm. The Norwegian Nature Index is a good example in biodiversity research [see the next section].

"There are two things: we want to reduce uncertainty and we want to deal with it. To reduce uncertainty, predictions probably would be a useful tool. For me the big question is whether the goal of formulating precise predictions can actually be reached. I tend to believe that eventually entropy keeps increasing. If we cannot actually reduce uncertainty, and we have to deal with it, then predictions and scenarios may primarily help us to see what alternative futures may be in the coming. And then based on good scenarios you can actually build strategies and try to be proactive." (Joseph)

When scientific results are used for policy advice, uncertainties become multidimensional. This situation calls for what political scientist Giandomenico Majone (1989) called *feasibility analysis*: exploring the conditions of possibilities and impossibilities when striving for particular societal goals. However, in Majone's view, feasibility analysis includes an element of active intervention to change perceptions about what is possible and what is not. Properly specified uncertainty might actually help in this regard (Pe'er et al. 2014b).

3.3 Multiple uncertainties in a well-elaborated case: The Norwegian Nature Index

The Norwegian Nature Index (NNI) is a framework for integrated measurement of the state of Norwegian nature and its biodiversity, mandated by a government decision in 2005. The NNI is based on more than 300 individual indicators representing a wide range of species, populations, and indirect indicators of biodiversity (e.g. dead wood), covering nine major marine, freshwater and terrestrial ecosystems (Certain et al. 2011, Nybø et al. 2011, Nybø et al. 2012). For each indicator, values were assessed or estimated for various geographical entities (municipalities, counties, the whole country), for the years 1950, 1990, 2000, and 2010, as well as for a hypothetical reference state used as a basis for scaling all indicator values to the same scale from 0 (worst) to 1 (best). The reference state was generally supposed to represent rather intact ecosystems with minimal human impact, except for the mainly semi-natural ecosystems of "open lowlands".

The process of developing the NNI revealed different types of uncertainties, from the traditional issues of precision and accuracy of natural science data to the more fundamental issues of the meaning of biodiversity and interpretation of the concept of the reference state. The assessments of indicator values were based partly on actual data and modelling, partly on expert judgement, and often on a combination of both. For most indicators, available data were not statistically robust, due to, for instance, a low number of subjectively-selected sites. Hence, some form of expert judgement or 'model-based inference' (Yoccoz et al. 2001) was required in extrapolating from measured or observed data to years and sites where such data were lacking.

This type of uncertainty is within the scientific paradigm that most natural scientists are comfortable with. They have some data and knowledge about their indicator and the ecosystem(s) it is part of, and they can, with more or less confidence, say what the state of a particular indicator might be at different times and sites, even though actual observations are lacking.

It turns out, however, that individual experts vary considerably in their ability or willingness to use their expert knowledge to extrapolate indicator values beyond the set of observed values, and several have expressed concerns about the uncertainty involved in such extrapolations (Aslaksen et al. 2012a, Figari 2012). Paradoxically perhaps, it appears that experts used to working with the most accurate and precise population data were also the ones most reluctant to use their presumably excellent expert knowledge to extrapolate beyond their observations. Nevertheless, the uncertainties related to lack of accuracy, precision and spatial and temporal data coverage can be addressed by better sampling design and/or more samples in future data gathering.

The most immediate question of uncertainty in constructing the NNI appeared at the very beginning of the development process: How can a complex phenomenon, such as biodiversity, be captured by just a few indicators, and which indicators should be included to represent the state of nature and biodiversity? The core group in charge of the project decided early on to focus explicitly on biodiversity components as far as possible, i.e. by mainly using indicators based on some form of species population levels or indirect indicators with close association to species, and to avoid indicators representing direct drivers.

The actual selection of indicators was done by the invited experts in cooperation with the core group and was based on a specified set of criteria. The possible biases stemming from the selection process were then reduced by including more rather than fewer indicators and by weighing each indicator in such a way that each functional group defined had the same overall weight in the index (e.g., many primary producers were equivalent to a few decomposers). Some experts pointed to the uncertainty as to whether this resulted in an index sufficiently sensitive to key direct drivers and thereby producing an NNI relevant to the mandate.

In assigning values to the NNI, the experts were not just asked to assess values for their indicators for the present (2010) or previous years, but also to give their best assessments of indicator values for the future (2020), given current management policies for the relevant ecosystem (Aslaksen et al. 2012b). Such projections into the future raise new elements of uncertainty. Partly this may be seen as a statistical problem of forecasting based on time series of previous observations. However, only few indicators have sufficiently long time series of data with adequate precision to support credible forecasts.

In addition, most experts found it difficult to consider forecasting without worrying about some potential fundamental changes in management policies or ecosystem dynamics. A similar type of uncertainty may apply to assessment of indicator values in the somewhat distant past (e.g., 1950), where little credible supporting information may be available for most indicators. Such 'back-casting', as well as forecasting, would force the expert to address a more basic kind of uncertainty than the mere lack of precision or accuracy in the existing observations, namely the uncertainty of whether the fundamental dynamics of their ecosystems are preserved over time or not.

Perhaps the most challenging type of uncertainty about the NNI pertains to how the reference state is understood. It relates to more than a mere starting point for measurement. For each indicator, the experts must also link the concept of a reference state to the significance of observed changes in their indicators for the state of nature and biodiversity and decide on a scaling model for this relationship. Also, unless the various indicators relate to the same concept of a reference state (at least for the same major ecosystem), the values of the indicators cannot be compared or aggregated into one index.

For all major ecosystems except "open lowlands", a reference state based on intact natural ecosystems with minimal human impact was specified. However, various operational interpretations of such a reference state were allowed, reflecting quite different perceptions of the appropriate basis for comparisons against the current state among the experts. Some had fundamental objections to a reference state of 'pristine nature', others felt the overall objective of the NNI was better reflected by a reference state of sustainable management of ecosystems, whereas others simply found it impossible to decide on indicator values for a 'pristine' reference state. The conceptual uncertainty about the reference state continues to challenge the experts and their approach to the NNI.

3.4 Contingencies of adaptability

The public understanding of biodiversity may involve an unrealistic perception of a desirable static balance, but the components of biodiversity are evolving. Species survive in the long term only if they manage to adjust to environmental variation. Evolution is an existential game, and success means ability to stay in the game (Slobodkin and Rapoport 1974). This was Darwin's original insight. Yet this process has been embedded in historical contingency. The adaptability of different components of biodiversity depends on the time frame. Micro-organisms can adapt very quickly, as the continuous origin of resistant strains shows (Fisher et al. 2012), whereas elephants and polar bears are much less adaptable over the same time scales.

"In some directions in conservation biology, we try to incorporate evolutionary aspects as well. My question is: to which extent should we differentiate our biodiversity management in saying that we ignore such adaptive processes and the way species are able to incorporate them, or that we focus on them and say, well, it's not relevant what we have now, the only important thing is to maintain the process of adapting to a stochastic and changing world. Such an approach would imply very different conservation strategies from what is the dominant approach today. On the other hand, views on conservation have changed a lot in the past [Haila 2012]. It seems to me that orienting somewhere along the middle between these two perspectives may be an appropriate strategy." (Klaus)

This consideration points toward another, dynamic source of uncertainty in conservation: we are facing a big question mark on how to improve the correspondence between human-induced changes in the environment with the dynamics of crucial habitat features critical to particular groups of organisms – across a range of temporal scales (Haila 2007).

3.5 What about ecosystem services?

Ecosystem services are relative newcomers in the conceptual repertoire of conservation biology. It is not self-evident that the goal to safeguard ecosystem services is congruent with the goal of biodiversity protection (see Harrington et al. 2010 for an overview). Some people fear that an emphasis on ecosystem services will result in a loss of biodiversity from sight (Skroch and López-Hoffman 2009; Henle et al. 2012). If we primarily want to extract something out of nature, we do not necessarily need biodiversity. The concept of ecosystem services is essentially based on human valuation systems, which are often equated quite narrowly with changing consumer preferences, willingness to pay, and technological advances (Vira and Adams 2009). If such a utilitarian view dominates and biodiversity is ignored unless it provides us with services, then one can reasonably say: get rid of most of it. This is likely to happen, at least at some scales.

Also, ecosystem services can be specified using several criteria that may be connected with biodiversity in different ways. Biodiversity and ecosystem services are often clearly coupled, but problems arise when measures to protect ecosystem services have contradictory effects on biodiversity (Cardinale et al. 2012). This brings uncertainties in the form of trade-offs into practical management decisions: an operation aiming to achieve a particular benefit may be harmful to other benefits.

"Biodiversity and ecosystem services are very different; the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES), for instance, considers them as two separate issues, exactly so they don't compete with each other. What I like about both terms is that at least as ideas, they are both scale-independent. But questions arise when you try to measure either of them. The measures have to be scale-dependent. You cannot measure biodiversity on the global scale in the same way you would monitor changes on local scales. Neither can you consider the same set of ecosystem services, and their fluxes, at the local or global scales. --- So, if we can, at least, agree that the concepts of biodiversity and ecosystem services are both important at a given scale, then we can reduce some of the uncertainty that could come up if we try to always link the two concepts as if they were equal." (Guy)

4. Social and political reception

4.1 Institutions and governance

The adoption of formal institutional devices, such as laws and policy documents, create uncertainties as well. Unclear goals, or goals imposed from above, can create significant conflicts and legitimacy problems (Keulartz and Leistra 2008). Also, there is considerable uncertainty in policy processes and their outcomes. Command and control regulation may backfire (Holling and Meffe 1996). The problems may also induce decision-making frames with a significant degree of discretion for those implementing laws. Informal institutions, such as habits, contact networks, and working traditions, produce further sources of uncertainty in the shape of conflicts or trade-offs between policy, law, and implementation. As Brian Wynne (1992) in particular has convincingly argued, the trustworthiness of public institutions is an essential factor influencing public perception of risks.

"But on the other hand, talking about the uncertainty of institutions gets often far too general. Institutions were actually created to reduce uncertainty in social life. But failure is always possible; analogously, we have market failures, we have state failures, and so on. I think this brings forth one dimension of uncertainty in social life. Furthermore, you may have a rule in social life but you cannot really predict whether people follow this rule. Perhaps it is followed as a statistical pattern, but you can never predict whether specific persons behave in a specific way." (Christoph Görg)

Conditions of stability and predictability of social institutions raise general questions concerning good governance. It is not obvious what the ideal relation between good governance and uncertainty should be. Uncertainty is a pervasive phenomenon in social life in any case, so the question of whether to reduce uncertainty or cope with uncertainty becomes particularly acute in this context.

"We can say that we have a good governance process when the process itself is good, when its output is good, and/or when the outcome, i.e., the consequences of this process are good [Rauschmayer et al. 2009]. Different criteria are used as to what we mean by good. For example, we can say that a process is fair when everybody has a chance to raise voice, which in an extreme case would agree with the Habermasian ideal of discourse ethics, free of domination. --- We could also say a process is good if it leads to a good output such as a binding agreement. But one could also claim that what is really relevant are the consequences that process and output have on the ground." (Felix)

The scale of the political governance system and the size of administrative units it covers matters as well (Haila 2002, Meadowcroft 2002). There are inherent uncertainties in management; what is to be managed is not only the system, but also the reaction caused by the governance process itself. This situation calls for learning and adaptive management (see, e.g., Holling et al. 2002). Adaptive management requires flexibility and reflexivity, i.e. the capacity to make new kinds of decisions when new information emerges or conditions change. However, regulatory decisions should be predictable and the rights and duties clearly defined (Craig 2010, Ruhl 2011). Normative elements are at the background of actual policy measures and the legal rules they build upon.

"Every policy strategy, every law is always a compromise, built upon different interests and power relations related to such interest. A law or governance measure in itself is not good governance, but it is real governance. It includes some interests and power relations and so on, but we have to reflect in a normative way on how to improve this." (Christoph)

4.2 Assessing governance success

A difficulty with assessing consequences of particular governance measures, such as the process of designing the Natura 2000 network or reforming the Common Agricultural Policy in Europe, is that the effects of specific conservation measures get diluted over time into changes in the society due to other kinds of processes. The temporal scale is important in this context. Big changes do not take place overnight. In fact, 20 or 30 years may be a very short time for essential change to take place. We ought to think more in terms of social and political dynamics, their temporal matching and mismatching, and their mismatching with ecological processes (Cumming et al. 2006, Henle et al. 2010).

"I very much like the idea of starting with accepting knowledge gaps and, despite this, realising that we have to do something. It is more motivating to look at processes instead of necessarily looking at the final outcomes. We have the same problem in ecology where sometimes we simply need to find some rules that govern the system, because such rules are more robust to uncertainty. --- We also need to consider trade-offs, for instance in the case of inefficient funding: we may put a lot of efforts into conservation and restoration but they fail because of a parallel process which may be more effective, and completely contradicting the first one. I think that agri-environmental schemes are an excellent example [Henle et al. 2008]. Governments put a lot of money into agri-environmental schemes, but in parallel put about ten times more money into intensive agriculture, which wipes off possible positive effects [Pe'er et al. 2014a]. This definitely increases uncertainty in the realm of governance." (Guy)

A possible approach to assess the uncertainty, which is inherent to policy instruments, is to take the aims at face value (for literature on environmental-policy evaluation, see e.g. Birnbaum and Mickwitz 2009). If the objective of a particular instrument is straightforward, we might check afterwards whether the outcome was as it was meant to be. This possibility would be one characteristic of a successful policy closure [Sect. 5.1].

However, policies can change so quickly that indicators on what follows on the ground are lagging behind. The time-lag in feedback from policy to on-the-ground actions not to speak of time-lag in ecosystem processes is a critical aspect of uncertainty when it comes to informing politicians about what is effective and what is not. People who live close to nature often know very well the systems their sustenance depends on, and should be heard. They also often have good intuition on how different policies influence their livelihood.

Also, objectives of various policies may be diffuse to start with, and they may have been designed specifically to be diffuse to decrease tensions between different sectors of administration. Or there may be sheer lack of coordination between the sectors. For example, many agricultural and other subsidies are contradictory to biodiversity policies (Henle et al. 2008).

"For me the question is: How can we provide guidance to improve the governance of biodiversity, not governance in general? Are we far enough that we can say something specific, or can we merely offer a list of potentially important things without giving specific advice? --- Probably there is no single rule how to assess the governance process for improving chances of success. And also, probably we need different tools depending on the main goal, so perhaps clear diversification of goals and assessment of their synergies and incompatibilities is a good idea." (Klaus)

4.3 Economic instruments

The protection of biodiversity touches on economics in several ways. First of all, effectiveness and efficiency of policy instruments as well as their distributional effects need to be considered. Management measures produce costs through effects on accustomed sustenance that may be hard to evaluate in advance and, with an even higher degree of uncertainty, the measures might also produce benefits. Whereas costs of biodiversity conservation, in the form of opportunity costs associated with land-use restrictions or of direct management costs, mostly accrue to local actors, conservation benefits often reach far beyond local and regional boundaries (Perrings and Gadgil 2003, Ring 2008). Furthermore, the costs and benefits are not distributed evenly among stakeholders, e.g., public versus private, or rich versus poor.

As a consequence, various types of regulatory and economic instruments must be included in the toolbox of biodiversity management (Ring and Schröter-Schlaack 2011). Market-based instruments are often specific enough to be amenable to empirical follow-up. In settings with good closure, cost-benefit-type calculations can certainly be valuable, albeit with reservations because the temporal horizon is restricted. Ecological economists have argued that current market prices give a notoriously unreliable standard for calculations covering any length of time into the future. Therefore, apparent precision of monetary estimates is deceptive (Spangenberg and Settele 2010).

The strict requirement of cost-benefit optimality can be relaxed, but indicators and qualitative measures are necessary, and applying an evolutionary perspective to policy-making rather than a static-equilibrium-oriented perspective helps in this context (Ring 1997; van den Bergh and Gowdy 2000).

"We don't know the optimal solution at a certain point in time. It is more important to try as far as possible to move into the right direction, if you can say what the right direction is. This is relevant for the precautionary principle: it is easier to find the right direction than try always to do the optimal thing. Adaptive management builds upon a similar idea: if you are able to at least measure some properties related to sustainability, we should be able to see whether a course of action will lead in that direction, more or less." (Irene Ring)

Another major issue is that all goals cannot be reached everywhere at the same time: priorities have to be defined, and choices have to be made, at least in part by weighing costs and benefits. This creates uncertainty: Are the weights appropriate? In this context, Maclaurin and Sterelny (2008) make a good case in favour of using *option value* as a framework, i.e., assessing potential benefits of preservation on a long temporal horizon, uncoupled from immediate market valuation. Estimating option value brings uncertainty about the future explicitly into the assessment. Maclaurin and Sterelny (2008) showed by examples that specification of the options created by biodiversity, leaning on empirical knowledge to the extent possible, helps to reach a decision despite uncertainty. Through this effect, as they note, " (t)he crucial point about option value is that it makes diversity valuable." (p. 154).

The use of option value as a framework is a close kin to another decision rule recommended by economists in a situation of uncertainty: the strategy of the second best, i.e., setting goals that are more robust than the calculated optimum, which may be unattainable anyway (Lipsey and Lancaster 1956-1957, Majone 1989).

4.4 Precaution

The precautionary principle originated in the context of environmental policy and the volume of the literature on the topic is huge (as an introduction, see Harremoës et al. 2001, EEA 2013). Biodiversity loss has received its share (e.g., Cooney and Dickson 2005), but the relevance of the precautionary principle clearly varies across policy fields. It is central in the case of health and hazardous chemicals (e.g., Kriebel et al. 2001), but its applicability in biodiversity is more ambiguous.

"The precautionary principle is tricky and allows different interpretations. There was a huge contestation between the United States and Europe on what the precautionary principle exactly means in the biodiversity convention and the Cartagena protocol. It is not only about uncertainty, it is more about the possible impact of something that we perhaps do not really understand." (Christoph)

The demand for precaution is the more convincing the better we can delineate alternative options and their concomitant uncertainties, but it is relevant also under less stringent conditions (EEA 2013). The complexity of biodiversity issues means that we can only give relatively general rules on what is relevant and what is not. Above all, it is imperative to increase understanding of what different instruments mean for the real world if they are enforced.

"I think that the protection of biodiversity and maintenance of ecosystem services can potentially go in opposite directions as regards the precautionary principle. Conservation of biodiversity is based on the assumption that we should protect biodiversity for its own sake, in accordance with the precautionary principle. We assume that it is beneficial also for humans, but it is valued for its own sake. However, in the context of ecosystem services attention to biodiversity is conditional upon its effect on specific ecosystem functions." (Jukka Similä)

In other words, in the latter case uncertainty is more troublesome: we want to know what the service in question is and reduce uncertainty as to what actually follows when we protect a certain asset. Notwithstanding, as regards systems poorly known, precaution will remain a very important principle.

4.5 The concept of biodiversity and its surrogates

Ultimately, the aim to protect biodiversity has to make sense to a broad public that forms an *active public*; an idea building on the classic formulation of the dynamics of publicity by John Dewey (Dewey 1927; see Hajer and Wagenaar 2003). Assessing the conceptual basis of the biodiversity concern can give rise to different opinions

(Maclaurin and Sterelny 2008). Conceptual confusion may contribute to general uncertainty about the relevance of the issue.

"What is biodiversity? There is some conceptual ambiguity. First of all there is often uncertainty about proper objects of research and management. Is it species numbers, is it genetic variability, or is it life on Earth? This gets down to the question: What are the goals of conservation efforts? A specific question in this respect is how to deal with exotic species [Davis et al. 2011, Simberloff 2011]. --- This ambiguity has been enhanced and made even more difficult on the normative side by the connection between biodiversity and other equally ambiguous terms like ecosystem functioning or ecosystem services. So the relation between biodiversity and ecosystem functioning has increasingly come into the discourse about biodiversity. We're threatened by a vicious circle: protect biodiversity to maintain ecosystems, and protect ecosystems to maintain biodiversity." (Kurt Jax)

One way to clarify the confusion is to draw a distinction between the brief characterisation of biodiversity in the Convention on Biological Diversity versus problems that arise when it is applied to policy or management. On general terms, the brief definition provided by the convention can be considered clear and quite satisfactory, but it does not easily transform into guidelines.

"We need to decide which components of biodiversity we want to focus on. A number of policy documents are not clear about this. For instance the goal of higher biodiversity to me is meaningless." (Erik Framstad)

This source of uncertainty demands that one should clearly recognise the context in which the term biodiversity is used as an argument. The term may give rise to problems as biodiversity can be operationalised in alternative ways (e.g., Sarkar and Margules 2002). There is no simple way to conclude which one is most productive. Perhaps there is also linguistic vagueness because the way we use terms varies a lot. Linguistic and terminological variation thus brings another element of uncertainty into the game.

"Another issue is how much power and weight different parties have in the discussion [Latour 1987]. There are so many different ways of aggregating multi-criteria matrices to forge indicators of biodiversity that very often people lose any idea of what the weights mean. A really important aspect is that there is no objective way of deciding which indices should be used. --- I think some of these discussions come up in monitoring in an analogous fashion. The problem always comes up: What should we monitor? We want to monitor biodiversity. And then somebody is monitoring some components of it, and somebody else says that you are not monitoring biodiversity. Often, both are right." (Klaus)

Seemingly, uncertainty about what biodiversity is may create serious confusion with respect to what to monitor, where and how (Henle et al. 2013). In this context, reducing uncertainty would be highly welcome.

5. Communication and societal relevance

To succeed in the aim of protecting biodiversity, conservation biologists need to learn to get their message through. When exploring the concept of causality, Herbert Simon (1977, p. 52) noticed that in a social context causality is analogous to what physicists have called "action at a distance", i.e. material interference without an immediate physical contact. He continued the line of thought with an aphoristic remark: "no influence without communication".

This idea is worth taking seriously. However, it is self-evident that communicating the need to protect biodiversity to the society at large is much more demanding than merely spreading a message. To become influential, the communication has to strike a cognitive chord.

5.1 Aiming at closures, albeit temporarily

A specific message needs a specified context. This principle corresponds to the demand that satisfactory closure conditions are necessary for a satisfactory scientific explanation (Dyke 1988). Similarly, closure conditions are important in formulating policy guidelines that can be implemented (Hajer 1995), especially in the short term when concrete decisions have to be made.

To further specify this demand, we can use Herbert Simon's (1981, p. 190) characterisation of the idea of "bounded rationality" as " (t)he meaning of rationality in situations where the complexity of the environment is immensely greater than the computational powers of the adaptive system." This description certainly fits situations in which choices have to be made between alternative ways of protecting biodiversity: Draw together all relevant knowledge you have, and do the best you can. On a longer temporal horizon, it is important to value chances for flexibility, potential for making new choices in new situations.

A too hastily formed closure is, however, vulnerable to type III error: answering the wrong question (Dunn 2001, Kriebel et al. 2001, see Haila and Henle 2014). Or, in other words, the answer may connect to an unproductive contrast space (Garfinkel 1981, Sect. 2.1 above, Haila and Henle 2014).

Depending on the nature of the closure, the concomitant uncertainty is bounded as well. The better the understanding of the structure of a system under research, the more uncertainty is bounded (Smith 2007). That is true also of the ontological dimension of uncertainty. When modelling the variability of a particular ecological system, one cannot expect a huge change in the values of relevant variables in a very short time. Furthermore, we know well enough basic population dynamics of different kinds of organisms to formulate realistic expectations, for instance, in a comparison between the population growth rates of lemmings versus polar bears.

"Differentiation between goals might help and trigger fruitful discussions. There are certainly policy goals, which have obtained so good a closure that it does not matter what the values of the people are. For instance, speed limits on motorways. Just make a speed limit and it does not matter what people think. After a new rule is enacted, people change their ways and values when they learn to follow the rules. Norbert Elias called this the technisation of society [Elias 1995]. But one could draw distinctions between different kinds of governance processes, depending on the clarity of the closure [Haila 2008]. Actually, closure is a pretty good notion for analysing such situations." (Yrjö Haila)

However, closure is always temporal and contextual. Any proposed closure can be challenged, and established closures can be opened up to further consideration. Speed limits may be lowered in residential areas, in the vicinity of primary schools or fire stations, and so on. A historical demonstration of changes both in closure and norms is offered by regulation of hunting and species protection (Pohja-Mykrä et al. 2005, Haila 2012, Klenke et al. 2013).

5.2 Enhancing public discussion

Uncertainty can serve as an entry point to discussions, even concerning quite complicated issues, such as the relationship between ecosystem services and biodiversity. Uncertainty may play an important role. It is a question of communication, how we can use uncertainty instead of blowing it up all the time to levels where we just do not communicate at all (see Pe'er et al. 2014b).

We also need to take into account the potential that uncertainty offers for opponents of environmental concerns, as the example of climate sceptics shows (UCS 2004, Pielke 2005). Another aspect to take into account is emphasized by ecologists communicating with conservation NGOs about potentially misguided actions that may turn counterproductive. Improved understanding of the sources of uncertainty might show ways toward reconciliation of opposing opinions (Chris Margules, personal communication].

"For raising awareness about specific problems, uncertainty may create difficulties, but it may stimulate public discussion. But if you want to define policy strategies you have to look for costs and benefits, you have to look for side effects, and therefore you need some knowledge. --- It is much better to communicate uncertainty than to speak with a strong conviction: this is the result, this is the truth, the scientific truth." (Christoph)

It is well known that conflicts can also provide entry points to fruitful discussions. This, however, depends on the nature of the conflict. For instance, the establishment of the Natura 2000 network in the EU has given rise to local conflicts in several countries. If such conflicts lock in as contests of prestige between authorities and local inhabitants, the consequences may be mainly detrimental, and this is what largely happened in Finland (Hiedanpää 2002, Björkell 2008). A similar case was reported from Poland:

"Then the main approach of regional administration was to engage local politicians and authorities into consultation programs to try to talk to them and perhaps manage the conflict a little bit. A source of uncertainty at this stage was the relevance of social conflicts. Then there was new recognition of importance of local communities, especially landowners and people in charge of community-owned land at the municipal level. We as a research team tried to provide the authorities a diagnosis of the local conflicts of opinion, or at the very least insight into the consultation process and the role of stakeholders, but the policy priorities were different. If the focus on managing conflicts and landowners and local communities had been present from the beginning, the process might have looked quite different." (Joanna Cent)

Given a communicative start, however, conflicts could become occasions of mutual learning. Local conflicts have the potential of bringing specific questions into focus, such as how to combine biodiversity preservation and local livelihoods.

"A potential conflict might bring different opinions into the open; for instance if nobody knows in advance what different stakeholders think about, say, the Natura 2000 process and what the consequences are for them. A research project functions almost like an intervention. --- And so such a situation is a fantastically interesting case of the potential of using uncertainty to enhance fruitful discussions. In fact, the process in Poland took quite a long time, something like five years. There would have been enough time for fruitful communication." (Yrjö)

5.3 Deliberation and social learning

According to the view of political scientist Maarten Hajer (2009), deliberation is primarily about defining the meaning of different policy alternatives. Scientists can support such a process by being aware of the possibility to adopt alternative roles in public discussions.

"Negotiations are possible, based on the common ground, eventually. The first step, the first stage in order to find common ground and negotiate is to understand different logics, different knowledges, and that basically we scientists are one specialist party, and there are many other people with completely different opinions." (Joseph)

The development of the Nature Index for Norway is an interesting example in that it has a very ambitious aim: to have an instrument to provide an overall assessment of how well Norway maintains nature and avoids loss of biodiversity [Sect. 3.3 above]. With the various statistical and more fundamental uncertainties inevitably associated with the NNI, one may question whether such an objective will ever be obtained. The experts involved in the process expressed concern, but they still considered the resulting index values to be reasonable for their respective ecosystems (Figari 2012). Also, the NNI may have another important role to play as a basis for discussion with various stakeholders about the meaning of biodiversity and our custodianship of nature. By discussing the basic concepts of the NNI, as well as the range of decisions made during the process, stakeholders of various sectors may conduct an increasingly informed debate about nature and biodiversity.

"I've been in this sort of game for 30 odd years, communicating with policy makers and lay people. I'm not sure if I have really taken on the role as an advocate as such, to any great extent. But of course we communicate with different people, within different contexts. If I am talking to journalists or others who need to have a fairly simplified message to their readers, I probably do not spend a lot of time making any complex statement with a lot of uncertainties about this and that. Also, when communicating with bureaucrats who are there to execute policy, we often get criticised for not being clear enough; they dislike that. --- But in the context of the Norwegian Nature Index, we also had a lot of debate with a broader audience beyond natural scientists, particularly on forests, that was really the one nature type where everybody had opinions. We've been going around to local municipalities, talking to the forest managers, the officials at the municipality level, plus representative forest owners. And it's surprising how benign and accommodating they are – it is a process that seems to be leading to greater consensus about the aim of the project, and how it can be useful." (Erik)

Another interesting dimension of public deliberation has been raised by the potential tension between general goals and specific applications. It is generally assumed that specific topics offer grounds for fruitful discussion, but this is not always the case.

"Under which conditions does collaborative learning work, so that people merge towards a common understanding despite differing goals, and when it doesn't work? What does this difference mean for our approach in the management? An example I can give is a study in the context of a conflict on the establishment of a nature reserve in which the utilisation of different spatial representations were compared. When they used virtual spatial experimentation that was not representing the real case study, it worked. But when they used the real map this was not helpful. People were too concerned to secure their own claims and not open to look for solution where all would be better off. [Barnaud et al. 2013]" (Birgit)

6. Conclusions: collective effort with a division of labour

Biodiversity praxis draws upon a diverse combination of specialised skills that range from field work and data analysis to formulating management targets or policy goals and lobbying for implementation. As Pielke (2007) points out, scientists can adopt different roles when interacting with society at large. Our aim in the Leipzig workshop reached further, however. In addition to discussing what kinds of different identities scientists can adopt, it is crucial to establish fruitful interactions among scientists who have adopted different roles. The notion of semantic space helps in this regard. Scientists, managers and policy-makers specializing in different aspects of biodiversity praxis could address together such aspects of uncertainty that are closest to their respective expertise. In particular, identifying dimensions of the semantic space of uncertainty in biodiversity praxis may facilitate collective learning (Haila and Henle 2014).

The semantic space is multidimensional. Haila and Henle (2014) presented a preliminary scheme with five dimensions: [i] data; [ii] proxy; [iii] concepts; [iv] targets, policy and management; [v] normative goals. In this scheme, however, societal aspects are collapsed together. One could easily add several more dimensions – until the whole structure becomes intractable. Uncertainty is a cluster concept, all types of uncertainty cannot be addressed simultaneously. A more fruitful possibility to make the idea of semantic space usable in practice is to reduce the dimensionality "step-by-step" by specifying what kind of interactions can be distinguished among a specified set of dimensions.

Managing Natura 2000 sites offers an example. On the one hand, there are field surveys, and reports offering conclusions on the conservation values of any particular site. On the other hand, there are needs and wishes of local people and visitors. The problem is to fit these two sets of factors together.

"Of course, if it is an absolutely unique site, then there is no way to undermine the idea that this is a valuable site that has to be preserved. But if it's not, as Natura areas usually aren't, then there are potentially other things to consider, also compensatory procedures. So it's not only that the conservation goals should be watered down, it's also that conservation goals can be enriched by some kind of societal considerations." (Yrjö)

The accustomed methodology of scientific research includes elements that point toward cooperation that promotes learning. Our task is to grab the opportunity.

"What we are mostly discussing is basically a scientific cycle within science. But then we also have the societal cycle, which is as large if not much larger – society with its own processes, or if you want, socio-economics. --- The stronger the links are, the more adaptive, for instance, management can be. So the idea of participatory modelling, for instance, is that the process itself is more compact. That's the process also of developing good monitoring, or a good index: to put more and more people together, and then perhaps we can pack the societal and scientific processes, to get more adaptive and quicker, and better respon to uncertainty." (Guy)

Also, work on the local level offers other kinds of potential openings for fruitful learning processes. There is a discrepancy that stems from the generality of global recommendations and the specificity needed in local contexts.

"The problem of scales becomes acute when you think the (local) system you are working with is closed, but it's not, and that means that what you are doing is not achieving what you believe it will achieve. So the question for me here is not how you can make sure that the information from the outside gets into the local scale. Rather, the question is, how can you provide those who work on the local scale good enough guidance on when they have to go outside of the local scale, and when they can work on the local scale. --- Even if it's not essential for the particular case they should at least be aware that a larger scale exists." (Klaus)

Finally, the normative background of the concern over biodiversity requires attention because it gets mingled with all other dimensions of biodiversity praxis. Biodiversity preservation is basically a normative principle. It has a very strong material basis in the human biospheric dependence, but the normativity breaks through because there are always several ways to reach particular goals, the more so the more general the goals (Haila 2004, Maclaurin and Sterelny 2008). In other words, biodiversity protection is ethically driven, throughout. This challenge has a pragmatic side, too: the value of ecosystem processes and biodiversity has to be integrated into our perception of economic and social development.

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