Halting biodiversity loss: how social–ecological biodiversity research makes a difference

Marion Mehring, Barbara Bernard, Diana Hummel, Stefan Liehr & Alexandra Lux

To cite this article: Marion Mehring, Barbara Bernard, Diana Hummel, Stefan Liehr & Alexandra Lux (2017) Halting biodiversity loss: how social–ecological biodiversity research makes a difference, International Journal of Biodiversity Science, Ecosystem Services & Management, 13:1, 172-180, DOI: 10.1080/21513732.2017.1289246

To link to this article: https://doi.org/10.1080/21513732.2017.1289246

© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

Published online: 24 Feb 2017.

Submit your article to this journal

Article views: 1222

View Crossmark data

Citing articles: 4 View citing articles
Halting biodiversity loss: how social–ecological biodiversity research makes a difference

Marion Mehring \(^{a,b}\), Barbara Bernard \(^{a,b,c}\), Diana Hummel \(^{a,b}\), Stefan Liehr \(^{b,d}\) and Alexandra Lux \(^{a,e}\)

\(^{a}\)ISOE – Institute for Social-Ecological Research, Biodiversity and People, Frankfurt am Main, Germany; \(^{b}\)Senckenberg Biodiversity and Climate Research Center BiK-F, Ecosystem Services and Climate, Frankfurt am Main, Germany; \(^{c}\)German Advisory Council on the Environment, Zoological Garden Frankfurt, Frankfurt am Main, Germany; \(^{d}\)ISOE – Institute for Social-Ecological Research, Water Resources and Land Use, Frankfurt am Main, Germany; \(^{e}\)ISOE – Institute for Social-Ecological Research, Transdisciplinary Methods and Concept, Frankfurt am Main, Germany

**ABSTRACT**

In 2010, there was a bold commitment to take action in halting global biodiversity loss by 2020. Now, halfway through the Convention on Biological Diversity strategic plan 2011–2020, the success of the mission is under discussion. With the Twelfth Conference of the Parties attesting a lack of action, attention is now focused on the science–policy interface. This article offers a critical examination of the current debate on the science–policy interface and its implications for biodiversity research. The aim is to demonstrate the need for a social–ecological perspective. First, we argue that there is not only a lack of action but also a lack of knowledge. Second, we present social–ecological systems as a common framework for biodiversity research. Third, we explain the potential of transdisciplinarity in biodiversity research. We finish by calling for a decisive turning point to consider the hybrid notions of biodiversity in science, politics and conservation activities.

1. **Introduction**

The Global Biodiversity Outlook 4 ([SCBD] Secretariat of the Convention on Biological Diversity 2014) provides serious indications that the pressures on biodiversity will continue to increase until 2020 while its status simultaneously declines. Furthermore, Tittensor et al. (2014) conclude that despite ongoing policy and management responses, the impacts of these efforts are unlikely to result in any improvement to biodiversity by 2020. In response to this, the Twelfth Conference of the Parties (COP) to the Convention on Biological Diversity (CBD), held in Pyeongchang, Republic of Korea in 2014, identified key actions in order to address the issue (UNEP 2014). The CBD recommended measures that countries can take, depending on national circumstances and priorities, to accelerate the implementation of the Strategic Plan for Biodiversity 2011–2020 and to facilitate the achievement of the Aichi Biodiversity Targets (UNEP 2014). However, some CBD member countries rejected to include this list of key actions into the main decision and thus only allowed it to be annexed. This fact decisively weakened the role of the key actions.

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was initiated in 2010 and aimed to strengthen the science–policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity. IPBES is the intergovernmental body assessing the state of biodiversity and of the ecosystem services for society. Being policy relevant but not policy prescriptive, IPBES aspires to create a new type of science–policy interface (Görg et al. 2010; Borie & Hulme 2015). For this reason, the IPBES Conceptual Framework was developed in order to facilitate cross-disciplinary and cross-cultural understanding (Díaz et al. 2015a). This framework is a simplified model of the interactions between nature and people seeking to embrace not only different disciplines but also different knowledge systems (Borie & Hulme 2015; Díaz et al. 2015a). In this regard, different scholars claim that biodiversity knowledge organisations such as IPBES must acknowledge the ontological and epistemic plurality of biodiversity and related values (see Spierenburg 2012; Turnhout et al. 2012; Borie & Hulme 2015; Díaz et al. 2015a; Chan et al. 2016).

This article is a critical examination of the current debate on the science–policy interface and its implications for biodiversity research. First, we argue that despite the ongoing national and international endevours, there is not only a lack of action but rather a lack of knowledge at three levels (Becker 2002; Jahn et al. 2012): system knowledge for a better understanding of the causes and impacts of biodiversity loss, orientation knowledge for determining the opportunities and constraints of decision-making and transformation knowledge for identifying ways and means of realising such
decisions. Integrated research is needed in order to bridge this gap. Second, we outline social–ecological systems (SES) as a common research framework in current biodiversity research, based on a transdisciplinary research approach. Third, we show how a transdisciplinary research approach can bridge the identified gap in knowledge. We conclude by presenting characteristics of the type of social–ecological biodiversity research that we advocate.

2. Not only a lack of action but also a lack of knowledge

The fact that the parties of the CBD identified the need for a plan of action to achieve the Aichi Goals by 2020 indicates that they assume a lack of action. A list of key actions and recommendations for implementation was adopted. In line with this last COP in 2014, Tittensor et al. (2014: 244) conclude in their mid-term analysis of progress towards international biodiversity targets that ‘efforts need to be redoubled to positively affect trajectories of change and enable global biodiversity goals to be met by the end of the current decade’. The Thirteenth COP in Cancun, Mexico in December 2016 will provide some indication of how useful these key actions have been.

According to McCarthy et al. (2012), the lack of action corresponds to a lack of financial efforts for conservation funding. However, from a governance perspective, Swiderska et al. (2008: 48ff.) conclude that the investments in biodiversity should not be limited to protected areas and conservation. They argue for mainstreaming biodiversity in other policy fields such as national development and poverty-reduction strategies or sectoral planning issues. In this regard, they notice a lack of integration in mobilising substantial resources for an effective biodiversity policy. Among others, Swiderska et al. (2008: 128ff.) see a lack of capacity on the part of individuals, communities and organisations as an additional obstacle to governing biodiversity. Allowing local communities to play an active role in shaping conservation initiatives and securing their rights to resources gives them a key incentive to participate in and sustain biodiversity conservation (see Ostrom et al. 1999; Dietz et al. 2003; Mehring et al. 2011). This is crucial for a better linkage between policies (both international and national) and local conditions/priorities (participatory processes, improve transparency etc.).

As we will argue, the relationships between these shortcomings have to be recognised. Cash et al. (2003) summarise that the efforts to mobilise science for sustainability are more likely to be effective when they address boundaries between knowledge and action. It is particularly important to analyse the factors that lead to a lack of action (e.g. lack of interest and motivation, or different priorities across key players) and consider how these relate to insufficient financing and integration, and what capacities for more expedient processes are required. Furthermore, many studies show that to enhance knowledge about the status of threatened species and implement successful measures for their protection, one needs to take into account the respective economic, societal and political conditions (e.g. Ban et al. 2013; Jaramillo-Legorreta et al. 2007; Carpenter et al. 2009; Collins et al. 2011; Mitchell et al. 2015). There have been a lot of discussions already on the lack of knowledge on biodiversity, especially in the beginning of IPBES (Loreau et al. 2006). However, these were very often focused on a general lack of knowledge or biased towards natural science-based knowledge (Lariguaderie et al. 2012). A first conclusion that can be drawn is that there is a need to improve the knowledge base for the conservation and sustainable use of biodiversity. This is a plea for learning more about the conditions and correlations surrounding conservation efforts and making it a major topic for social sciences and integrated transdisciplinary research.

In attempting to bridge this lack of knowledge about (the loss of) biodiversity, it is crucial to deal with ignorance (e.g. about undetected species), contested knowledge (e.g. access to biodiversity and benefit sharing) and uncertain knowledge (e.g. trade-offs or multifunctionality of biodiversity). The complex nature of biodiversity loss always leads to uncertain knowledge. And inactivity as a consequence of uncertainty will result in yet more losses – a situation which is irreversible on human timescales.

Thus, synergies must be built among different knowledge systems in order to provide the science–policy community with the basis that is needed to decide on the right course of action to halt global biodiversity loss and to maintain related ecosystem services (Thaman et al. 2013). This implies integration of different knowledge holders and their academic or practical expertise (Tengö et al. 2014; Martín-López & Montes 2015). Going beyond the scientific community, one needs to consider the knowledge produced, transferred and used by various stakeholders and organisations (Cornell et al. 2013). Moreover, approaching biodiversity loss as a ‘wicked’ problem (Sharman & Mlambo 2012) requires the consideration of different types of knowledge. In general, the discourse on problems of non-sustainable development differentiates between the following three types of knowledge (Jahn et al. 2012: 8):

- **System knowledge**: the (analytical and theoretical) knowledge involved in trying to understand an issue, that is, for a better appraisal and evaluation of interactions and (non-) sustainable developments;
• Orientation knowledge: the knowledge with which to identify opportunities and the constraints of decision-making. This is required, for example, to differentiate between desired and undesired developments and for the formulation of criteria and indicators for more sustainable developments;

• Transformation knowledge: the knowledge of the ways and means of implementing such decisions – for the development of appropriate and feasible options for action.

In relating these different knowledge types to biodiversity research, it is easy to become entangled in various needs for knowledge. The interrelation between biological processes (e.g. data about extinction risks) and societal conditions (e.g. data about the use of biodiversity and ecosystem services differentiated by characteristics such as age, gender and educational or ethnic background) is a substantial part of system knowledge. How do ecological and societal processes interact? What are effects and feedbacks? What issues emerge from these interactions? Questions related to governance-like capacities and financial resources primarily belong to transformation knowledge: What factors facilitate different types of action? What barriers exist? Finally, it is when mainstreaming biodiversity into society to overcome the lack of integration that orientation knowledge is needed: Which ecosystem services should be protected, which disservices avoided? For example, different types of knowledge are required with regard to annual global timber production and supply trends. Data published by the FAO is frequently modelled or estimated, yet figures are not consistently reported for each country and generally tend to be more accurate for developed countries than for developing countries: system knowledge on the supply and demand of timber is needed. There is also a need for improved knowledge on trade-offs between timber production and other forest ecosystem services (such as regulating services or non-timber forest products): orientation knowledge on which ecosystem service (timber production) is managed in the expense of another (non-timber forest products) is essential. Finally, achieving a global and regional sustainable and just balance between timber supply and harvest, transformation knowledge is needed on barriers such as, for example, power relations (see Leadley et al. 2014).

Acknowledging this knowledge gap, the international research platform Future Earth is designed to provide knowledge needed to support transformations towards sustainability. It claims to address the grand global sustainability challenges, including biodiversity loss, by following an interdisciplinary approach (Future Earth 2014a, 2014b).

‘safeguard the terrestrial, freshwater and marine natural assets underpinning human well-being by understanding relationships between biodiversity, ecosystem functioning and services, and developing effective valuation and governance approaches’ represents one of eight key challenges that should be addressed in sustainability research. The Strategic Research Agenda 2014 of Future Earth claims for ‘a novel way of doing science’, including ‘a strong emphasis on full integration among scientific disciplines, on engagement with societal partners in co-designing and co-producing knowledge, on international collaboration, on producing knowledge that is valuable to decision makers, and on generating the solutions that society needs’ (Future Earth 2014a: 9). However, the implementation of the research agenda has not progressed far enough to assess its impacts. Lots of hope is given to the current process of implementing Knowledge-Action-Networks (www.futureearth.org/knowledge-action-networks).

A major challenge when it comes to this need for new or recombined knowledge is the hybrid notion of biodiversity in science, policy and conservation as a value-laden concept (see also Turnhout et al. 2013). In addition, the need for conservation and sustainable use is also an ethical and moral question (Jax et al. 2013) and it has to be acknowledged that different values such as intrinsic, instrumental and relational values are expressed by people (Chan et al. 2016). Decision makers have to deal with this complexity and a careful weighting of different trade-offs is needed. The role of scientists is in assisting in that by creating the evidence base for responsible decision-making (Spiersenburg 2012). This requires a careful study of the dynamics within SES including the different trade-offs (ibid).

3. Social-ecological systems as a common framework

A factor contributing to this complexity is that the dynamics of biodiversity are not strictly attributed to either the ‘natural’ or the ‘social’ sphere, but are inherently characterised by intricate interactions between nature and society – so-called human–nature interactions (Glaser et al. 2012). From a theoretical perspective, these interactions can be described as ‘societal relations to nature’ (Becker et al. 2011; Becker 2012). Societal relations to nature emerge from the culturally specific and historically variable practices by which human beings, groups and societies shape and regulate their relations to nature on local, regional and global scales. Societal relations to nature take shape and must be regulated at different levels: at the micro level via the individual satisfaction of needs and provisioning activities with the benefits
of relevant ecosystem service; at the meso level via the regulation of supply systems and resource utilisation and at the macro level via the regulation of societal and ecological reproduction and integration (Becker 2012: 41). Regulation is understood here as a dynamic process of iterative or interwoven interactions between mutually dependent factors. The discussion about basic needs within the sustainability discourse emphasises basic societal relations to nature such as nutrition, water supply, mobility, housing and shelter, etc. These are elementary and indispensable for both human reproduction and societal development, and a failure to regulate them can have far-reaching consequences and adverse effects.

The crisis-prone development of societal relations to nature means that this social–ecological perspective must take a problem-oriented perspective. The core of the research is about the conditions for sustainable transformation and regulation of these nature–society interactions. The concept of societal relations to nature distinguishes between the physical-material and cultural-symbolic aspects of relations. It is then possible to examine how different natural and societal structures and processes are selectively and dynamically linked, thus allowing societal relations to nature to be described and analysed as a SES (Figure 1).

Global biodiversity loss can be conceived as a crisis-prone development of societal relations to nature. Despite a great deal of uncertainty, ignorance and contested knowledge surrounding the phenomenon, there is a high demand for evidence-based political decision-making. At the same time policymakers face the challenge to decide whether action should be taken at a national or regional level (Görg et al. 2010). Different trade-offs in using biodiversity and ecosystem services occur: temporal (benefit now – cost later), spatial (benefit here – cost there), beneficiary (some win – others lose), service (manage for one service – lose another) (Spierenburg 2012). Turnhout et al. (2013) argue that institutions and regulations dealing with biodiversity must incorporate wide diversity of knowledge, understanding and evaluation of the subject. If one looks at global biodiversity loss in the context of a SES, it becomes clear that societal and natural structures and processes are tightly interwoven (see Figure 1). The SES is a system nested in both nature and society. Different actors influence the natural system and its ecosystem functions. The natural system provides ecosystem services and also ecosystem disservices that are harmful to society. Biodiversity has key roles at different levels of the ecosystem services hierarchy: as a regulator of underpinning ecosystem processes, as a final ecosystem service and as a good (Mace et al. 2012; Balvanera et al. 2014). Thus, biodiversity loss is not only decisively influenced by societal processes but can itself have severe impacts on society.

Linking biodiversity dynamics to a SES framework allows for a better understanding of the complexity of biodiversity loss, its dynamics, interactions and processes on different scales as well as enabling the inclusion of social considerations (Ban et al. 2013; Carpenter et al. 2009; Fischer et al. 2015; Martín-López & Montes 2015). From a problem-oriented perspective, the analytical core of the SES should be determined by specific social–ecological structures and processes of nature–society interrelations: societal practices on the use of biodiversity and ecosystem services; different types of knowledge on how to manage biodiversity and ecosystem services; institutional settings that constitute the regulatory mechanisms for using biodiversity and for conservation; as well as technology installed to conserve and use biodiversity and ecosystem services (see Figure 1).

It is interesting to note that the initial recognition of the strong linkages between society and nature has resulted in a growing demand for biodiversity to be addressed via an integrative...
approach (Liu et al. 2007; Carpenter et al. 2009; Palomo et al. 2014). The concept of ecosystem services has increasingly been included in research objectives, policies and international initiatives (e.g. MEA 2005; TEEB 2010; Díaz et al. 2015b) over the past two decades (Reyers et al. 2013; Martinez-Harms et al. 2015) with the aim of investigating the links between ecosystems and human well-being. Still, these interactions continue to be studied by separate scientific disciplines (Liu et al. 2007). The thorough and unbiased integration of ecology and biodiversity along with sociocultural and non-monetary values remains a major challenge which carries with it the risk of financial exploitation of nature (Martín-López et al. 2014; Poe et al. 2014; Gavin et al. 2015; Silvertown 2015; Rissman & Gillon 2016). The concept of ecosystem services is claimed to be an auspicious approach designed to connect nature and society (Schröter et al. 2014). However, there is still a vital discussion on the notion (Chan et al. 2016), current understanding (Abson et al. 2014) and initial intention (Gómez-Baggethun et al. 2010) of values within the concept of ecosystem services. A major controversy arose while framing biodiversity within the Conceptual Framework of IPBES (Díaz et al. 2015b) through either the utilitarian notion of ecosystem services or the holistic notion of ‘mother earth’ (Borie & Hulme 2015). Integrating the latter, the Conceptual Framework claims to go further than any previous science–policy interface in its incorporation of knowledge systems (such as indigenous and local) other than western science (Díaz et al. 2015a). However, honouring this plurality of knowledge still has to be proven in the upcoming future (Borie & Hulme 2015). Soberón and Peterson (2015) even argue that the Conceptual Framework is simplifying drastically the complexity especially of indigenous and local knowledge and question the fact that one single Conceptual Framework can provide some sort of Rosetta Stone (Díaz et al. 2015a) covering the different scales (especially regional, national and local) including the relevant stakeholders thereof. The integration of different kinds of scientific and practical knowledge, as well as integrated perspectives on interactions among natural and social processes are also a major challenge for the Strategic Research Agenda 2014 of Future Earth that seeks ‘to co-produce knowledge across cultural and social differences, geographies and generations’ (Future Earth 2014a, 2014b). In general, a variety of frameworks for analysing SES currently exists; they vary significantly as to their theoretical and disciplinary origin, their purpose and the way they conceptualise the social and the ecological system as well as the interaction thereof (Binder et al. 2013). However, this diversity is important because it reflects the complexity of research questions and purposes addressed by the different frameworks (ibid).

4. The role of transdisciplinarity

There is an increasing consensus in sustainability science in general that new ways of knowledge production are needed (Cash et al. 2003; Tengö et al. 2014) as expressed in the co-design and co-production discussion within Future Earth (Future Earth 2014a). However, biodiversity science still lacks a diversity of knowledge and framings (Turnhout et al. 2013) and progress in the use of knowledge produced from ecosystem services science remains insufficient (Bennett et al. 2015). Transdisciplinarity can provide adequate answers to these challenges, since it seeks to integrate different kinds of knowledge (scientific, professional, practical and everyday knowledge). Transdisciplinarity describes a new ‘principle of research and science’ rather than a method (Mittelstraß 2005), and can be understood in terms of a critical and self-reflexive research approach that relates societal to scientific problems. A major characteristic of transdisciplinary research is its reference to real-world problems such as sustainable development or natural resource management (Klein et al. 2001). Referring to Jahn et al. (2012), we see how three consecutive steps of an ideal transdisciplinary research process can be distinguished (Figure 2): (1) a common research object must be established by scientific and societal stakeholders, which translates the real-world problem into a scientific issue; (2) new knowledge is then produced by means of interdisciplinary collaboration and (3) the new knowledge is evaluated both for its contribution to societal and scientific progress. In research practice, this ideal model helps to structure the research process in terms of defining the research subject, goals and research questions and developing the solution-oriented research design.

Transdisciplinarity in biodiversity research is critical, as biodiversity research addresses more and more the underlying societal causes and effects of biodiversity loss (Mehring et al. 2012). Furthermore, addressing the challenges in the application of the ecosystem services approach, especially the trade-offs (see Spierenburg 2012), a transdisciplinary approach is essential. Transdisciplinary biodiversity research is conducted at the interface of society and science by integrating different types of knowledge (system, orientation, transformation) (see Figure 2). It addresses biodiversity loss as a ‘boundary object’ and the concept of ecosystem services can be interpreted as a key concept for the integration of diverse
knowledge related to sustainability (Star & Griesemer 1989; Becker 2012; Abson et al. 2014). In this way, transdisciplinary biodiversity research seeks to facilitate a mutual learning process between science and society. At an international workshop on opportunities and challenges of transdisciplinary biodiversity research experts, representatives and decision makers summarise the added value as (i) a better exchange of knowledge between different stakeholders (on use and conservation of biodiversity), (ii) a better link to practical local knowledge on biodiversity and (iii) increased acceptance of the results (Mehring et al. 2012).

Acknowledging that human societies are highly interconnected with the biophysical system, the SES framework conceptually formalises this interdependency (Martín-López & Montes 2015). Taking the value plurality into account (Chan et al. 2016), the current framing in biodiversity research must be opened to views, knowledge and non-academic stakeholders (Turnhout et al. 2012). Thus, sustainability science addressing the different types of knowledge such as system, orientation and transformation (see Figure 2) emerges as the body of knowledge able to understand this complex interaction (Martín-López & Montes 2015). Martin-López and Montes (2015) argue that the current challenge of biodiversity conservation must be addressed through the operationalisation of sustainability science. Coevolving sustainability science including the different types of knowledge such as system, orientation and transformation (see Figure 2) with SES research mutually co-benefits in order to pursue inter- and transdisciplinary collaboration (Partelow 2016). By focusing on nature–society relations in a transdisciplinary context, one can offer an integrated vision on biodiversity loss. Not only the assessment and monitoring of biodiversity dynamics become relevant but also questions as to ‘which biodiversity and related ecosystem services should be protected’ or ‘what factors facilitate/impede different types of action’. At the same time, attention must be paid to not subsume biodiversity under more general topics perceived to be more relevant (e.g. water food energy nexus) and loose ground for biodiversity research.

5. Social–ecological biodiversity research

We call for a decisive turn in current biodiversity research to take into account the hybrid nature of biodiversity (sitting between science, politics and conservation activities) and address the different knowledge types. Conserving the diversity of life requires an acknowledgement of the diversity of values and knowledge involved (Turnhout et al. 2013). In order to bridge the current gap between needs and action we need a fundamental transformation designed to (re) frame biodiversity research. A social–ecological perspective addressing a crisis-prone development of societal relations to nature and incorporating the above identified knowledge types – system, orientation and transformation knowledge – is necessary to overcome this challenge.

In summary, we argue for a social–ecological transdisciplinary biodiversity research that is

- Normatively focused on the sustainable use and conservation of biodiversity, with the aim of
preserving the continuity of social–ecological structures and processes. Orientation knowledge is needed to address the question ‘What should we do?’ (normative level).

• Systemically conceptualised through SES via critical analysis of the non-sustainable regulation and transformation of biodiversity use and protection. The focus will be on social–ecological structures and processes with changing patterns of interactions between actors and ecosystem functions delivering ecosystem services. System knowledge is needed to address the question ‘What is true?’ (descriptive level).

• Problem-oriented because it implies a strong reference to operative, strategic activity and to concrete, controllable and affordable solutions to specific problems of non-sustainable use patterns of biodiversity and ecosystem services. The integration of scientific and practical knowledge is a high priority at this stage (cf. Jahn 2015). Transformation knowledge is needed to address the question ‘What can we do?’ (operative level).

Taking the vision from Future Earth that ‘a new type of science that links disciplines, knowledge systems and societal partners’ (Future Earth 2014b) seriously into account, we believe that the presented three qualities of social–ecological transdisciplinary biodiversity research and their interdependencies are crucial for the success of addressing the grand challenges, including biodiversity loss.

Acknowledgements

We thank our colleagues from ISOE – Institute of Social-Ecological Research, Frankfurt am Main/Germany Thomas Jahn, Engelbert Schramm, Robert Lätkemeier and Lukas Drees, for the joint conceptual work on social-ecological systems. We further thank our colleagues from the Senckenberg Biodiversity and Climate Research Centre BiK-F, Frankfurt am Main/Germany Karen Hahn, Katja Heubach, Thomas Hickler, Lasse Loft and Uwe Zajonz, for the discussion on earlier versions of the SES framework. We also thank two anonymous reviewers for helpful and supportive comments on the manuscript. Finally, we are particularly grateful to Wolfgang Cramer for helpful comments on the overall idea of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[SCBD] Secretariat of the Convention on Biological Diversity. 2014. Global biodiversity outlook 4. Montréal; p. 155 pages.

Abson DJ, von Wehrden H, Baumgärtner S, et al. 2014. Ecosystem services as a boundary object for sustainability. Ecol Econ. 103:29–37.

Balvanera P, Siddique I, Dee L, et al. 2014. Linking biodiversity and ecosystem services: current uncertainties and the necessary nets steps. BioScience. 64:49–57.

Ban NC, Mills M, Tam J, et al. 2013. A social-ecological approach to conservation planning: embedding social considerations. Front Ecol Environ. 11:194–202.

Becker E. 2002. Transformations of social and ecological issues into transdisciplinary research. Paris (FR), Oxford (UK): UNESCO Publishing/EOLSS Publishers.

Becker E. 2012. Social-ecological systems as epistemic objects. In: Glaser M, Krause G, Ratter BMW, Welp M, editor. Human-nature interactions in the Anthropocene. Potentials for social-ecological systems analysis. New York (US), London (UK): Routledge.

Becker E, Hummel D, Jahn T. 2011. Gesellschaftliche naturverhältnisse als rahmenkonzept. In: Groß M, editor. Handbuch Umweltsociologie. Wiesbaden (DE): VS Verlag.

Bennett EM, Cramer W, Begossi A, et al. 2015. Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr Opin Environ Sustainability. 14:76–85.

Binder C, Hinkel J, Bots PWG, Pahl-Wostl C. 2013. Comparison of frameworks for analyzing social-ecological systems. Ecol Soc. 18:26.

Borie M, Hulme M. 2015. Framing global biodiversity: IPBES between mother earth and ecosystem services. Environ Sci Policy. 54:487–496.

Carpenter SR, Mooney HA, Agard J, et al. 2009. Science for managing ecosystem services: beyond the millennium ecosystem Assessment. Proc Natl Acad Sci USA. 106:1305–1312.

Cash DW, Clark WC, Alcock F, et al. 2003. Knowledge systems for sustainable development. Proc Natl Acad Sci USA. 100:8086–8091.

Chan KMA, Balvanera P, Benessaiah K, et al. 2016. Opinion: why protect nature? Rethinking values and the environment. Proc Natl Acad Sci USA. 113:1462–1465.

Collins SL, Carpenter SR, Swinton SM, et al. 2011. An integrated conceptual framework for long-term social-ecological research. Front Ecol Environ. 9:351–357.

Cornell S, Berkhout F, Tuinstra W, et al. 2013. Opening up knowledge systems for better responses to global environmental change. Environ Sci Policy. 28:60–70.

Díaz S, Demissew S, Carabias J, et al. 2015b. The IPBES conceptual framework – connecting nature and people. Curr Opin Environ Sustainability. 14:1–16.

Díaz S, Demissew S, Joly C, et al. 2015a. A rosetta stone for nature’s benefits to people. Plos Biol. 13(1):e1002040. doi:10.1371/journal.pbio.1002040

Dietz T, Ostrom E, Stern PC. 2003. The struggle to govern the commons. Science. 302:1907–1912.

Fischer J, Gardner TA, Bennett EM, et al. 2015. Advancing sustainability through mainstreaming a social-ecological systems perspective. Curr Opin Environ Sustainability. 14:144–149.

Future Earth. 2014a. Future Earth Strategic Research Agenda 2014. Paris: International Council for Science (ICSU).

Future Earth. 2014b. Future earth 2025 vision. Paris: ICSU.

Gavin MC, McCarter J, Mead A, et al. 2015. Defining biocultural approaches to conservation. Trends Ecol Evol. 30:140–145.

Glaser M, Krause G, Ratter BMW, Welp M, editors. 2012. Human-nature interactions in the Anthropocene. Potentials for social-ecological systems analysis. New York (US), London (UK): Routledge.

Gómez-Baggethun E, De Groot R, Lomas PL, Montes C. 2010. The history of ecosystem services in economic
theory and practice: from early notions to markets and payment schemes. Ecol Econ. 69:1209–1218.

Görg C, Nesshöver C, Paulsch A. 2010. A new link between biodiversity science and policy. Gaia. 19:183–186.

Hummel D, Jahn T, Schramm E. 2011. Social-ecological analysis of climate induced changes in biodiversity – outline of a research concept. Bi-K-F Knowledge. Flow Paper 11, Frankfurt/Main.

Jahn T. 2015. Theory of sustainability? Considerations on a basic understanding of “sustainability science”. In: Enders JC, Remig M, editors. Theories of sustainable development. Routledge studies in sustainable development. London (UK), New York (US): Routledge.

Jahn T, Bergmann M, Keil F. 2012. Transdisciplinarity: between mainstreaming and marginalization. Ecol Econ. 79:1–10.

Jaramillo-Legorreta A, Rojas Bracho L, Brownell, RL, et al. 2007. Saving the Vaquita: immediate action, not more data. Conserv Biol. 21:1653–1655.

Jas K, Barton DN, Chan KMA, et al. 2013. Ecosystem services and ethics. Ecol Econ. 93:260–268.

Klein JT, Grossenbacher-Mansuy W, Häberli R, et al. 2001. Transdisciplinarity: joint problem solving among science, technology and society. An effective way for managing complexity. Basel (CH), Boston (US), Berlin (DE): Birkhäuser.

Larigauderie A, Prieur-Richard AH, Mace GM, et al. 2012. Biodiversity and ecosystem services science for a sustainable planet: the DIVERsITAS vision for 2012-20. Curr Opin Environ Sustainability. 4:101–105.

Leadley PW, Krug CB, Alkemade R, et al. 2014. Progress towards the aichi biodiversity targets: an assessment of biodiversity trends. Policy scenarios and key actions. Secretariat of the convention on biological diversity. Montreal Canada Tech Ser. 78:500.

Liu J, Dietz T, Carpenter SR, et al. 2007. Complexity of coupled human and natural systems. Science. 317:1513–1516.

Loreau M, Oteng-Yeboah A, Arroyo MTK, et al. 2006. Diversity without representation. Nature. 442:245–246.

Mace G, Norris K, Fitter AH. 2012. Biodiversity and ecosystem services: a multi layered relationship. Trends Ecol Evol. 27:19–26.

Martinez-Harms MJ, Bryan BA, Balvanera P, et al. 2015. Making decisions for managing ecosystem services. Biol Conserv. 184:229–238.

Martín-López B, Gómez-Baggethun E, García-Llorente M, Montes C. 2014. Trade-offs across value-domains in ecosystem services assessment. Ecol Indic. 37:220–228.

Martín-López B, Montes B. 2015. Restoring the human capacity for conserving biodiversity: a social-ecological approach. Sustainability Science. 10:699–706.

McCarthy DP, Donald PF, Scharlemann JPW, et al. 2012. Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs. Science. 338:946–949.

MEA. 2005. Ecosystems and human well-being. A framework for assessment. Washington D.C. (US): Island Press.

Mehring M, Balian E, Berhault A, Schramm E. 2012. Transdisciplinary research on biodiversity – steps towards integrated biodiversity research. Frankfurt am Main (DE), Brussels (BE): ISOE/EPBRS.

Mehring M, Seeberg-Elverfeldt C, Koch S, et al. 2011. Local institutions: regulation and valuation of forest use - evidence from central sulawesi, Indonesia. Land Use Policy. 28:736–747.

Mitchell M, Lockwood M, Moore SA, Clement S. 2015. Scenario analysis for biodiversity conservation: A social-ecological system approach in the Australian Alps. J Environ Manage. 150:69–80.

Mittelstraß J. 2005. Methodische transdisziplinarität. Technikfolgenabschätzung – Theorie Und Praxis. 2:18–23.

Ostrom E, Burger J, Field CB, et al. 1999. Revisiting the commons: local lessons, global challenges. Science. 284:278–282.

Palomo I, Montes C, Martín-López B, et al. 2014. Incorporating the social-ecological approach in protected areas in the anthropocene. BioScience. 64:181–191.

Partelow S. 2016. Coevolving Ostrom’s social-ecological systems (SES) framework and sustainability science: four key-benefits. Sustainability Science. 11:399–410.

Poe MR, Norman KC, Levin PS. 2014. Cultural dimensions of socioecological systems: key connections and guiding principles for conservation in coastal environments. Conserv Lett. 7:166–175.

Reyers B, Biggs R, Cumming GS, et al. 2013. Getting the measure of ecosystem services: a social-ecological approach. Front Ecol Environ. 11:268–273.

Rissman AR, Gillon S. 2016. Where are ecology and biodiversity in social-ecological systems research? A review of research methods and applied recommendations. Conserv Lett. doi:10.1111/conl.12250

Schröter M, Van Der Zanden EH, Van Oudenhoven APE, et al. 2014. Ecosystem services as a contested concept: a synthesis of critique and counter-arguments. Conserv Lett. 7:514–523.

Sharman M, Mlambos MC. 2012. Wicked: the problem of biodiversity loss. Gaia. 21:274–277.

Silvertown J. 2015. Have ecosystem services been oversold? Trends ecol. Evol. 30:641–648.

Soberón J, Peterson AT. 2015. Biodiversity governance: a tower of babel of scales and cultures. Plos Biology. 13: e1002108.

Spierenburg M. 2012. Getting the message across biodiversity science and policy interfaces—a review. Gaia. 21:125–134.

Star SL, Griesemer JR. 1989. Institutional ecology, ‘translations’ and boundary objects: amateurs and professionals in Berkeley’s Museum of Vertebrate Zoology. 1907–39. Soc Stud Sci. 19:387–420.

Swiderska K, Roe D, Siegole L, Grieg-Gran M. 2008. The governance of nature and the nature of governance: policy that works for biodiversity and livelihoods [Internet]. IIED, London. [cited 2016 August 8]. Available from: http://pubs.iied.org/pdfs/14564IIED.pdf

TEEB. 2010. The economics of ecosystems and biodiversity: mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Tengö M, Brondizio ES, Elmqvist T, et al. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. Ambio. 43:579–591.

Thaman R, Lyver P, Mpande R, et al. 2013. The contribution of indigenous and local knowledge systems to IPBES: building synergies with science. IPBES Expert Meeting Report, UNESCO/UNU. Paris (FR): UNESCO.

Tittensor DP, Walpole M, Hill SLL, et al. 2014. A mid-term analysis of progress toward international biodiversity targets. Science. 346:241–244.

Turnhout E, Bloomfield B, Hulme M, et al. 2012. Listen to the voices of experience. Nature. 488:454–455.

Turnhout E, Waterton C, Neves K, Buizer M. 2013. Rethinking biodiversity: from goods and services to “living with”. Conserv Lett. 6:154–161.
UNEP 2014. List of potential key actions to enhance progress towards the implementation of the strategic plan for biodiversity 2011-2020 and the achievement of the Aichi biodiversity targets [Internet]. [cited 2016 August 8] https://www.cbd.int/doc/meetings/cop/cop-12/official/cop-12-09-add1-en.pdf.