Knowledge needs for the operationalisation of the concept of ecosystem services

Authors

1. Esther Carmen[1], Centre for Ecology & Hydrology, UK
2. Allan Watt, Centre for Ecology & Hydrology, UK
3. Laurence Carvalho, Centre for Ecology & Hydrology, UK
4. Jan Dick, Centre for Ecology & Hydrology, UK
5. Ioan Fazey, University of Dundee, UK
6. Gemma Garcia-Blanco, TECNALIA Research & Innovation, Spain
7. Bruna Grizzetti, European Commission, Joint Research Centre, Italy
8. Jennifer Hauck, Department of Environmental Politics, Helmholtz-Centre for Environmental Research, and CoKnow Consulting, Mühlweg 3, 04838 Jesewitz, Germany
9. Zita Izakovicova, Institutue of Landscape Ecology, Slovak Academy of Science
10. Leena Kopperoinen, Finnish Environment Institute SYKE, Finland
11. Camino Liquete, European Commission, Joint Research Centre, Italy
12. David Odee, Centre for Ecology & Hydrology, UK and Forest Research Institute, Kenya
13. Eveliene Steingröver, Wageningen Environmental Research (Alterra) , The Netherlands 14. Juliette Young, Centre for Ecology & Hydrology, UK

[1] Corresponding author: Esther Carmen, Centre for Ecology and Hydrology, Bush Estate, Edinburgh EH26 0QB, UK, +44 (0)131 4458443, esther.carmen78@yahoo.co.uk

Key words

Ecosystem services; operationalisation; knowledge needs; transdisciplinary research

Abstract

As environmental challenges and their management are increasingly recognised as complex and uncertain, the concept of ecosystem services has emerged from within scientific communities and is gaining influence within policy communities. To better understand how this concept can be turned into practice we examine knowledge needs from the perspective of the different stakeholders directly engaged with the operationalisation of ecosystem systems concept within nine socio-ecologically different case studies from different countries, levels of governance and ecosystems.

We identify four different but interrelated areas of knowledge needs, namely; (i) needs related to develop a common understanding, (ii) needs related to the role of formal and informal institutions in shaping action on the ground, (iii) needs related to linking knowledge and action, and (iv) and needs related to accessible and easy to use methods and tools. These findings highlight the need to view knowledge as a process which is orientated towards action. We discuss the potential to develop

---

[1] Corresponding author: Esther Carmen, NERC Centre for Ecology and Hydrology, Bush Estate, Edinburgh EH26 0QB, UK, +44 (0)131 4458443, esther.carmen78@yahoo.co.uk

transdisciplinary research approaches and the development of tools and methods explicit as boundary objects in the ecosystem service science community to develop more collaborative practices with other stakeholders and facilitate the operationalisation of the concept of ecosystem services across contexts.

Introduction

Environmental challenges and their management are increasingly recognised as complex and uncertain. As our understanding of these issues increases so does our awareness of the gaps in our knowledge and the need to address these gaps to increase societies' capacity to manage these issues effectively (Van Kerkhoff and Lebel, 2015, Pahl-Wostl, 2009). In addition to the need to develop scientific ecological understanding, the importance of understanding social and institutional processes, the interactions between governance levels, policy sectors and the need to include a broader range of stakeholder groups and their goals and values is recognised to help shape action that protects ecosystems (Wyborn, 2015b, Carmen et al., 2015, Prager et al., 2012). It is within this backdrop that the concept of ecosystem services, which presents a more integrated, systematic view coupling social and ecological components into one system, emerged from within scientific communities and is gaining influence within policy communities (Carpenter et al., 2009). The aim of this paper is to examine knowledge needs from the perspective of the different social actors directly engaged in decision making processes aimed at applying the concept of ecosystem services to better understand how the concept of ecosystem services can be operationalised and turned into practice more widely.

The ecosystem services concept focuses attention on the fundamental links and feedbacks between nature and society (Mace et al., 2012). Specifically the concept frames these links in terms of the benefits derived from ecosystem functions and processes to diverse social groups (Hauck et al., 2013). Critically, the main aim behind the development of the ecosystem services concept has been to more explicitly incorporate environmental dimensions into decision making and action (Daily et al., 2009), thus operationalising the concept of ecosystem services into practice.

Within the scientific community there has been a focus on developing various frameworks, knowledge and tools to assess and quantify these benefits (Bagstad et al., 2013). This has resulted in new collaborations, particularly between economists and ecologists to develop tools and knowledge on the economic value of ecosystem services, reflecting the increasing recognition of the need to work across disciplinary boundaries within scientific processes relating to the ecosystem services concept (Cornell, 2011). These developments have contributed to our understanding of the dynamics of different socioecological dimensions across contexts, but to a lesser degree have helped developed our understanding of the social and institutional factors that shape decision making processes, environmental practice and change processes more broadly to improve socio-ecological outcomes (Luederitz et al., 2015).

We use the term 'knowledge needs' to refer to the emerging recognition of different gaps in our capacity to help turn the concept of ecosystem services in practice. In this study we provide empirical evidence of these knowledge needs. First, we briefly outline the different conceptualisations of knowledge, highlighting different and often overlapping interpretations of knowledge, and current focus of enquiry in the ecosystem services science community. Secondly, we explain the inductive approach taken in this study to identify knowledge needs from the perspective of the multiple stakeholders involved in case studies driven by the ecosystem services research community and of EU level policy experts. Thirdly, we

present our findings organised around four key themes identified from the data. Lastly, we examine the implications of these findings for scientific communities to help facilitate the operationalisation of the concept of ecosystem services in practice. Specifically, this focuses on a critical reflection of knowledge production processes in a scientific context.

Conceptualisations of knowledge

Different types of knowledge

Knowledge is not easy to define and, as such, has led authors to conceptualise it and classify it in a variety of ways (Nutley et al., 2007). This includes distinguishing between traditional ecological knowledge and scientific knowledge (Berkes et al., 2000). Nutley et al. (2007) highlight distinctions made between empirical, theoretical and experimental knowledge. Empirical knowledge is often the most explicit and based on quantitative or qualitative research. Theoretical knowledge relies on theoretical frameworks (Potschin-Young et al., This issue) for thinking about problems either informed by research but more often than not based on intuition and informal approaches. Finally experimental knowledge, which is often tactic, based practice implicitly accumulated through operational experience from routines and behaviours in particular social setting and more challenging to articulate (Fazey et al., 2006, Boiral, 2002). Vink et al. (2013) distinguish between organised knowledge and unorganised knowledge. Organised knowledge being characterised as formal knowledge involving a wide consensus and therefore stability of understanding often crystallized in written or modelled form. Unorganised knowledge is characterised as involving collective puzzlement whilst moving towards wider agreement through interactive processes involving deliberation, learning and sharing. Failing et al. (2007) distinguish between fact-based knowledge claims and value based knowledge claims, the former referring to descriptive claims about the way the world is or might be and the latter referring to normative claims about how things should be, thus presenting more explicitly that knowledge is contested. It is however now more commonly agreed that knowledge is socially constructed and value laden (Adams and Sandbrook, 2013) and cannot be separated from its social and political context (Hannigan, 1995). Importantly, different types of knowledge are not mutually exclusive, rather knowledge is a continuum, for example between explicit and tactic knowledge or unorganised and organised knowledge, thus approaching knowledge as a static product may be overly restrictive (Boiral, 2002).

Knowledge production processes

Moving away from the linear, positivist view of knowledge as a static, tangible product that is easily defined and articulated which can then be readily inserted into decision making processes, there is an increasing focus on the flow of knowledge, as an dynamic, interactional process (Fazey et al., 2014). For example, through interactions between science, policy and practitioner communities to frame knowledge as a problem oriented process or the coming together of people and practices from different social groups to work together to produce new knowledge for mutual benefit and to facilitate change (Waylen and Young, 2014, Van Kerkhoff and Lebel, 2015, Rosendahl et al., 2015). In this study we use this broader, processes based perspective of knowledge. The broader perspective that views knowledge production as an interactional process is often referred to as knowledge co-production, where multiple stakeholders work collaboratively to share, explore, learn and shape new knowledge orientated around a real world

problem. More broadly if this approach is taken in research it is referred to as transdisciplinary research and represents a deliberate lack of any clear boundary between 'science' and 'policy' and 'experts' and 'users' in the collaborative production of knowledge (Wyborn, 2015a, Lejano and Ingram, 2009). This process-based perspective explicitly recognises different perspectives, knowledge gaps, uncertainty and thus not only known unknowns, but also unknown unknowns (Luks and Siebenhuner, 2007, Pawson et al., 2011). Importantly this methodological shift to a more process-based perspective of knowledge in research is often defined as a move from *mode 1* knowledge production, which involves the research community organised into disciplines objectively examining the outcomes of change, towards *mode 2* knowledge. *Mode 2* knowledge processes explicitly recognise subjective perspectives and mutual dependence between different social groups in society, and thus emphasises the importance of involving them in knowledge processes across different applicable contexts (Buizer et al., 2011, Lemos and Morehouse, 2005, Lang et al., 2012). One example of an approach that embodies mode 2 knowledge is adaptive co-management (Stringer et al., 2006, Armitage et al., 2009). However, a gap has been identified in many studies between the rhetoric of this approach and its application (Plummer & Armitage, 2007). This has led to calls for a focus on the methodological assumptions underpinning adaptive management, moving away from viewing ecosystem management as a technical problem towards broader perspectives that also embrace the social and institutional factors that shape these process Conservation Biology (Plummer & Hashimoto, 2011, Cundill et al., 2012). As a concept that embodies the need for an integrated approach, the operationalisation of the ecosystem services concept into decision making is also an excellent example of such an applicable context.

Current literature relating to transdisciplinary research and biodiversity and ecosystem services sciencepolicy interface processes (Rosendahl et al., 2015, Carmen et al., 2015) highlight the advantages of taking a broader view of knowledge as a process that involve multiple stakeholder groups to increase the likelihood of shaping solution orientated, policy relevant knowledge and outputs (Cash et al., 2003, Young et al., 2014). This includes new ideas, tools and methods to better inform decision making and support practical action. Often however transdisciplinary research is an ideal, and in reality stakeholders may be engaged in the process, but their knowledge may not be perceived as equally valid within an implicit hierarchy of knowledge which prioritises specific knowledge types. Indeed, this hierarchy is still often evident within scientific processes between qualitative and quantitative data (Adams and Sandbrook, 2013).

Within the scientific literature relating to ecosystem services two critical areas of enquiry currently involve of firstly, diagnosing problems across contexts, sometimes involving the views of different stakeholders, and secondly, identifying gaps in our knowledge (Carpenter et al., 2009, Hauck et al., 2013). Often studies are framed around the implicit assumption that this focus is sufficient to influence decision making beyond the realms of science (Daily et al., 2009, De Groot et al., 2010, Fisher et al., 2009). However, operationalisation involves going beyond simply highlighting the potential usefulness of the concept of ecosystem services for different social groups to facilitating its application in real world decision making processes to demonstrate its usefulness in addressing real world issues through practical experience (Jax, this issue). Despite the aim of the ecosystem services concept for the better use of knowledge in decision making, knowledge production so far has focused more on generating knowledge with less attention on better understanding the links between values, institutions, decisions and actions in knowledge

production and how to facilitate change that moves the concept of ecosystem services from an ideal into reality more widely (Braat and de Groot, 2012, Daily et al., 2009). From a broader perspective Flyvbjerg (2001) emphasises the need to not only focus on developing knowledge on why problems arise ('know why') that has been the more traditional domain of science, but also to develop knowledge on 'the how' ('know how'), which relates to what Aristotle termed as 'techne' and 'phronesis'. Whereas 'techne' is 'know how' that leads to developing knowledge products to meet a known goal, 'phronesis' is often equated with intuition, wisdom and judgment. In essence 'phronesis' is knowledge embodied in practical experience that, through time and reflectivity, helps shape capacity to navigate through unique combinations of factors embedded within particular settings (Shotter and Tsoukas, 2014). Phronesis encompasses both 'know-why' and 'know-how', which are all essential domains of knowledge to '*get things done'* (Bengt, 2011). From an ecosystem services research perspective a 'phronetic approach' focuses also on the development of capacity to engage in transdisciplinary research processes across different contexts to move from ecosystem services as way of thinking, to a way of doing.

This current focus in the ecosystem services literature and linear impact assumptions highlights the importance of not only taking a broad approach when examining knowledge needs in addition to examining these needs from the perspective of multiple stakeholders to better understand leverage points for the application of potentially useful concepts such as the ecosystem services beyond research communities. Our aim is firstly to take an inductive approach to examine the knowledge needs for the operationalisation of the concept of ecosystem services from the perspective of the multiple stakeholders exploring the usefulness of this concept in real world situations. Secondly, we aim to explore how the ecosystem services scientific community can better facilitate the use of the concept of ecosystem services beyond the traditional boundaries of science.

Methods and materials

Acknowledging diverse interpretation and the subjectivity of knowledge needs, an inductive, qualitative semi-structured strategy was used to provide a depth of understanding of knowledge needs from the perspective of the multiple stakeholders involved in the operationalisation of ecosystem service (Bryman, 2004). This provided contextual accounts of knowledge needs and gaps by exploring participants' perspectives and feelings on topics that matter to them (Mason, 2002, Arksey and Knight, 1999). Participants included stakeholders from research, practitioner and policy-based communities involved in nine cases studies with varying socio-ecological characteristics exploring the challenges and successes for the operationalisation of the concept of ecosystem services into practice by working with multistakeholder advisory groups. These case studies involved different levels of governance, aspects of the policy cycle and different policy sectors, reported in a basic questionnaire completed by each cases study leader (see Table 1). In addition a further case study was included from the EU level, involving 20 EU level stakeholders from different EC directorates and European Agencies and NGO's. The aim here was to ensure a range of socio-ecological contexts in the study to enable a broad understanding of knowledge needs widely applicable across the ecosystem services research community. Further background information on these case studies is outlined by Dick et al. (This issue). This multiple case study design

194 supported the identification of generalisations on knowledge needs applicable across contexts (Wiek et 195
al., 2012). The aim of this study was not to undertake a comparative analysis of different knowledge needs 196
between stakeholder groups, levels of governance or ecological settings.

	1 Finland (SIBB)	2 Slovakia (TRNA)	3 Spain (BARC)	4 Germany (BIOG)	5 Scotland (CNPM)	6 Netherlands, Belgium, UK (GIFT)	7 Italy (GOMG)	8 Scotland (LLEV)	9 Kenya (KEGA)
EU				✓		✓	✓	✓	✓
National		✓		✓		✓	✓	✓	
Regional		✓	✓	✓	✓	✓	✓		
Local	✓	✓	✓		✓	✓		✓	

197 **Table 1: Reported context of the participating case studies**

	Case study focus								
	1 Finland (SIBB)	2 Slovakia (TRNA)	3 Spain (BARC)	4 Germany (BIOG)	5 Scotland (CNPM)	6 Netherlands, Belgium, UK (GIFT)	7 Italy (GOMG)	8 Scotland (LLEV)	9 Kenya (KEGA)
Governance level									
Governance focus									
Legal	✓	✓		✓				✓	
Administrative	✓	✓	✓	✓			✓		✓
Political	✓			✓					
Planning	✓	✓			✓	✓			
Policy sector									
Agriculture		✓		✓	✓	✓			✓
Forestry				✓	✓	✓			✓
Freshwater						✓	✓	✓	
Urban	✓	✓	✓			✓	✓		
Protected area					✓	✓		✓	✓
Wildlife					✓			✓	✓
Bio-energy				✓					

198

199

200 The involvement of stakeholders in this study was voluntary and a combination of data collection
201 methods was used. This involved a focus group methodology with groups of stakeholders from each
202 case study and from the EU level and semi structured interviewing with researchers leading case
203 studies 1-9. The combination of methods used for each case study are outlined below (see Table 2).
204 **Table 2: Data collection methods**

Case study and data collection context	Data collection methods	Date
1. Operationalising ecosystem services in urban land-use planning in Sibbesborg, Helsinki Metropolitan Area, Finland	Focus groups and interview	February 2015
2. Landscape-ecological planning in the urban and peri-urban areas of Trnava, Slovakia	Interview	February 2015
3. A Green Infrastructure strategy in Vitoria-Gasteiz, Spain	Interview	February 2015
4. Bioenergy production in Saxony, Germany	Interview	February 2015
5. Improved, integrated management of the natural resources within the Cairngorms National Park, Scotland	Focus group	October 2014
6. Planning with Green Infrastructure in five linked cases in the Netherlands, Belgium and UK	Interview	January 2015
7. Nature-based solution for water pollution control in Gorla Maggiore, Italy	Focus group report and interview	January 2015
8. Quantifying the consequences of the European water policy for ecosystem service delivery at Loch Leven, Scotland	Focus group	September 2014
9. Operationalising ecosystem services for improved management of natural resources within the Kakamega Forest, Kenya	Focus group and interview	March 2015
10. EU Level stakeholders	Two parallel focus groups	January 2014

205

206 Focus group discussions were used to gather data with EU level stakeholders and from six of the nine
207 case studies. Semi structured interviews were used in combination with focus groups in three of these
208 six case studies. This combination of methods was used with stakeholders with higher levels of
209 engagement in the cases study who spoke a language other than English. It involved the case study
210 research leaders coordinating and facilitating the focus group discussion in the native language of the
211 stakeholders and feeding back issues discussed and exploring their own views and perspectives on

212 knowledge needs through semi structured interviews. In a further three case studies semi structured
213 interviews with case study coordinator team \members were used to collect data when it was to not
214 possible to bring together a group of stakeholders, which is an essential requirement for the focus
215 group methodology (Morgan, 1996).

216 The focus group method involves a facilitator actively stimulating discussions within a group on a
217 predefined topic (Morgan, 1996). Thus, group interaction is a key feature which distinguishes focus
218 groups from other qualitative methods (Smithson, 2000). A key advantage of group interaction is that
219 it can provide a more in depth understanding of issues by bringing together and exploring perspectives
220 in detail collectively (Peek and Fothergill 2009, Bryman 2004). Similarly, the semi structured
221 interviewing method also enables a predefined topic to be explored in detail, although this is explored
222 individually rather than collectively. Applying a semi structured approach to focus groups and
223 interviews involved developing a guide outlining the topics to be explored and during the discussion
224 the facilitator/ interviewer intervening only to probe responses and uncover more detail. Thus, the
225 facilitator surrendered a certain degree of control to the participants to take the discussions in
226 directions which they saw as important (Smithson, 2000).

227 To enable the lead case study researchers to apply the focus group method a detailed guide was
228 produced and discussed in depth before applying this method of data collection. This set out a clear
229 and consistent process for data collection across the different situations, types and numbers of
230 stakeholders in each case study. These guides set out how to begin the discussion by asking about the
231 conceptual frameworks of ecosystem services being used to frame the problem in each case study
232 which brought together existing knowledge on different components of socio-ecological systems and
233 set out relationships between them being explored. This enabled the discussions to identify knowledge
234 needs already considered in the initial phases of the case study. The discussions were then steered
235 towards exploring wider knowledge needs. Discussions were audio recorded with full, informed
236 consent obtained from participants before each focus group or interview. Audio recording ensured
237 that an accurate and full description of all the issues discussed. Recordings were then transcribed
238 verbatim and anonymity of the participants was maintained during the transcription, analysis and
239 reporting phase of the research.

240 Qualitative data analysis was undertaken using aspects of grounded theory (Strauss and Corbin, 1990)
241 using a thematic approach, as described by Ryan and Bernard (2003) which did not rely on a predefined
242 definition of knowledge. The analytical process firstly involved developing a familiarity with all the data
243 by thoroughly reading all the focus group and interview transcripts. Open coding was then applied in
244 an iterative process to organise segments of data from each transcript into sub themes based on
245 repetitions, similarities and differences in issues within the data. The sub themes were labelled based
246 on short phrases and words used to explain knowledge needs by the research participants and
247 organised into an analytical framework (Bryman, 2016). These sub themes and the data segments
248 within them were then grouped into four higher order themes to move from a descriptive to an
249 abstractive level of understanding from the data with a clear chain of evidence connecting back to the
250 raw data (Miles and Huberman, 1994). Each of the themes identified in the analytical process are
251 explained below. Following this the importance of these themes for the ecosystem services research
252 community in efforts to operationalise this concept into practice are explored. **Results**

253 Four themes were identified in the analytical process, which are described in this section.

Knowledge needs to develop a common understanding

254

255 The need for knowledge to develop a common understanding of the concept of ecosystem services
256 was highlighted as important by stakeholders who participated in this study to ensure that the core
257 principles of the concept were not diluted or 'lost in translation'. This relates to the need for more
258 effective communication and dialogue between stakeholders from different levels of governance,
259 policy sectors and from science, policy or practice based communities. These core principles
260 identified by stakeholders included embracing an integrated, systems perspective that cuts across
261 traditional disciplinary and sector boundaries, which requires the involvement of diverse groups of
262 actors across levels of governance from within research, policy and practice based communities.
263 Delivering multiple benefits is another core principle explicitly linked to the concept of ecosystem
264 services. Stakeholders recognised that developing a common understanding across diverse groups
265 takes time. However, building on existing relationships and networks was identified as one way to
266 help speed up this process. Alternatively, the role of boundary organisations or knowledge brokers
267 (boundary people) was identified by stakeholders as another possible way to develop a common
268 understanding between different stakeholder groups, for example between science based
269 stakeholders and policy based stakeholders.

270 To develop a common understanding of the concept of ecosystem services the need for a common
271 language was also identified. This involved the need for clear definitions, however some
272 stakeholders identified the usefulness of some ambiguity in terminology to facilitate dialogue and
273 the development of a common understanding between the different stakeholders in a specific
274 situation. Similarly, the need to translate language to link with the terminology used in policy and
275 practice based communities was also identified as a clear knowledge need by stakeholders to frame
276 decision making and shape action on the ground across levels of governance. For example, linking
277 with terms such as landscape services or green infrastructure. Adapting language in this way was
278 identified as a way to help facilitate a common understanding of the principles embedded in the
279 concept of ecosystem services across groups of actors with different perspectives.

280 Furthermore, knowledge needs identified also related the development and use of positive frames
281 to facilitate a common understanding of issues to bring together diverse groups of actors. Positive
282 messages may help in this way by signalling the synergistic opportunities and benefits from taking
283 integrated action. Conversely, stakeholders suggested that many arguments for the
284 operationalisation of ecosystem services applied negative frames that emphasise loss, adverse
285 impact and often focus on moral responsibilities. Sharing examples that explicitly highlight the
286 importance of and application of positive framing to meet a range of policy goals was identified as a
287 need. Stakeholders suggested this was an important step to help facilitate shared understanding of
288 the need for more integration and collaborative working across policy sectors.

289 Within a specific operational context once multi-stakeholders are brought together, stakeholders
290 identified the need for conceptual frameworks to help frame problems and develop a common
291 understanding of the need for an integrated approach. Specifically, stakeholders identified the
292 usefulness of frameworks for reducing complexity, whilst highlighting the links and feedbacks
293 between different components of the socio-ecological system. However, some stakeholders
294 emphasised the need to avoid presenting a linear relationship between different social and
295 ecological system components represented in frameworks to better acknowledge different but
296 equally important perspectives. Nonetheless, stakeholders highlighted the potential for frameworks
297 to help bring together different types of knowledge at the start of processes to develop a common
298 understanding of the problem and specific knowledge gaps to be addressed between those involved.

299 Overall developing a common understanding was identified as an overarching knowledge need to
300 contribute to the operationalising the concept of ecosystem services by helping to bring together

301 and facilitate dialogue between different stakeholder groups, across different contexts as an
302 important first step towards collaborative working to addresses context specific needs. A summary
303 of the knowledge needs to contribute towards developing a common understanding is provided in
304 table 3.

305 **Table 3: Summary of the knowledge needs to develop a common understanding between different**
306 **stakeholder groups**

Knowledge needs to develop a common understanding between the different stakeholder groups	☐ Maintain the core principles of an integrated approach and delivering multiple benefits that are embedded within the concept of ecosystem services.
	☐ Develop a common language across different stakeholder groups
	☐ Communicate by linking with existing policy concepts
	☐ Use positively framed messages to signal the potential relevance of the concept for different stakeholder groups
	☐ Use socio-ecological frameworks that emphasis the importance of an integrated approach involving multiple stakeholders

307

Knowledge needs on the role of formal and informal institutions in shaping action on the ground

310 Stakeholders identified the need to better understand how policy frameworks, structural and
311 organisational units (formal institutions) and norms (informal institutions) interact to shape action
312 on the ground. This included understanding how specific EU policy frameworks influence action in
313 relation to sustaining ecosystem services. For example, the Water Framework Directive and the
314 Common Agricultural Policy. Also included however was understanding the role of national policies
315 that are aimed at transferring management responsibilities of natural resources to the community
316 level by developing more meaningful interactions between policy/practice-based stakeholders and
317 local community stakeholders. Furthermore, the link between local policies and action aimed at
318 implementation was also identified as important, for example, the match between integrated
319 strategies and projects on the ground. This knowledge was emphasised as important to better
320 understand if and how to avoid the dilution of the principle of integration through the policy process
321 and across levels of governance.

322 Stakeholders also identified the need to better understand the role of norms in shaping how
323 organisations and groups of stakeholders think and act in approaching the operationalisation of an
324 integrated approach that is core to the ecosystem services concept. Specifically, stakeholders
325 emphasised the importance of organisational, sectoral and disciplinary cultures where integrated,
326 collaborative practices were normal. Thus reducing the likelihood of a mismatch between the goals
327 of different groups in planning and delivering integrated actions to manage ecosystems and the
328 services they provide. Examples of important collaborations were highlighted as including
329 governmental organisations, different departments and between scientists and local practice based
330 stakeholders, for example engineers and planners, in addition the current focus in science on
331 working with policy makers. Furthermore, the need to facilitate the multi-directional flow of
332 knowledge between different societal groups was also identified to enhance learning across
333 contexts. For example, across sectors and levels of governance levels. This included EU policy based
334 stakeholders identifying the need to understand why and how voluntary action to adopt a
335 perspective more in line with the ecosystem concept is applied in different organisations and
336 businesses.

337 Overall understanding the role of informal and informal institutions was identified as an overarching
338 knowledge need to help strengthen the development of integrated approaches, collaborative
339 working and learning between different stakeholder groups to better shape action on the ground. A
340 summary of the knowledge needs on the role of formal and informal institutions in shaping action on
341 the ground is provided in table 4.

342 **Table 4: Summary of the knowledge needs on the role of formal and informal institutions in**
343 **shaping action on the ground**

Knowledge needs on the role of formal and informal institutions in shaping action on the ground	☐ Understand the role of formal institutions across levels of governance in shaping action on the ground (for example, the EU Common Agricultural policy)
	☐ Overcome the cultural barriers (informal institutions) to collaboration in different stakeholder groups to normalise and strengthen collaborative practices between groups
	☐ Develop a better match between formal institutions (for example, local policies setting out the need for integration) and informal institutions (for example, implementation practice)
	☐ Facilitate the flow of knowledge (formally and informally) between levels of governance and sectors to help learning and spreading of ideas more widely

344

Knowledge needs to link knowledge and action

346 Stakeholders across case study contexts recognised that both knowledge and decision making
347 processes are complex and dynamic. However, the need for a strong link between these processes
348 was emphasised to produce 'actionable' knowledge. At the EU level this also included the need to
349 develop credible, useful data and information to feed back into knowledge and decision making
350 processes. Stakeholders emphasised the importance of an iterative process to both knowledge
351 production and action, which recognises the reality that decision making and action often has to
352 occur in the context of known knowledge gaps in policy processes. Thus knowledge production
353 should not be prioritised over action, with a need to bring these activities closer together.
354 Specifically stakeholders stressed that an iterative approach to collecting data, developing
355 knowledge and taking action was important and could help identify and address knowledge gaps
356 more quickly. The importance of relationships, trust and transparency between stakeholder groups
357 was emphasised as particularly important in this process. Furthermore, stakeholders also
358 emphasised a need to produce outputs with clear levels of uncertainty and guidance on its use to
359 minimise the likelihood of misuse of this information more widely in decision making processes.
360 Some researchers leading the case studies however emphasised the need to not link knowledge and
361 decision making too closely. This related to the need to provide a flexible space to experiment with,
362 adapt and develop scientific tools and scientific knowledge emerging from this. Researcher
363 stakeholders involved in the case studies also highlighted a lack of knowledge about if and how
364 knowledge being produced in multi-stakeholder processes was being used in decision making
365 processes.

366 All stakeholders involved in this study identified the need to better include a wider range of
367 stakeholder groups in processes aimed at applying the concept of ecosystem services in practice.

368 Although there are current multi-stakeholder groups from science and policy working together in
369 research processes framed around the ecosystem services concept and the core principle of
370 integrated perspectives to environmental management, the need for wider and deeper involvement
371 of other stakeholders in these processes was identified, for example businesses and local people.
372 Some research based stakeholder involved in the case studies identified the usefulness of
373 stakeholder involvement in knowledge production processes to help facilitate the development and
374 spread of ideas into the wider activities of all stakeholders involved.

375 Policy based stakeholders at the EU level identified the need for high quality knowledge from
376 research to help increase the credibility of action on the ground. There was also an emphasis on the
377 need for knowledge production to involve different stakeholder groups and their knowledge
378 alongside scientific stakeholders and their knowledge. EU policy based stakeholders identified the
379 need for this involvement throughout knowledge processes to provide a strong focus on the
380 development of useable/ relevant knowledge. More widely, stakeholders identified the need to
381 understand how to better facilitate this in practice, specifically relating to the challenges of bringing
382 together knowledge in different formats, from different stakeholder groups and from wider society.

383 Developing an understanding about how to overcome some of the barriers hindering closer working
384 and knowledge exchange across groups was identified by stakeholders as important. This included
385 knowledge on how to collaborate when only limited resources are available, for example developing
386 more innovative ways to involve wider social groups. Furthermore, the need to overcome low levels
387 of trust, for example shaped by previous difficulties with specific stakeholder or as a relic of
388 communist regimes was identified as an important need which influenced interactions between
389 stakeholders. The structure and transparency that some tools and methods provided was identified
390 as helping to facilitate trust and balance of perspectives in multi-stakeholder processes.

391 Overall, this theme draws attention to the need for knowledge production processes to be more
392 closely linked with action orientated processes, applying a collaborative, iterative approach involving
393 a wide range of stakeholders. A summary of the knowledge needs to bring knowledge orientated
394 processes and action orientated processes closer together is provided in table 5.

395 **Table 5: Summary of the knowledge needs to better link action and knowledge orientated**
396 **processes**

397 398 **Knowledge needs to** 399 **link knowledge** ~~**production and action**~~ **orientated processes**	☐ Apply an iterative approach to bring these more closely together whilst recognising that both knowledge and action are equally important.
	☐ ~~Develop collaborations that involve multiple stakeholders and~~ their knowledge from the start. For example, practice and policy based stakeholders.
	☐ Involve a wide range of stakeholders from policy based and science based communities collaborating from the start to develop relevant, useable knowledge that can readily feed into decision making processes
	☐ Meaningfully include a wide range of perspectives and knowledge from different stakeholder groups, including societal groups, for example businesses and local people

	☐ Develop closer multi-stakeholder collaborations by developing trust and being transparent.
	☐ Ensure space is created in collaborations for sharing of existing knowledge and developing new knowledge through experimental learning

400

Knowledge needs relating to methods and tools

A common knowledge need identified by stakeholders involved the development of simple, transparent tools and methods that could be applied across contexts. This need was identified to help assess the supply and demand of ecosystem services, synergies, conflicts and trade-offs across temporal and spatial scales and policy sectors and the different values attributed to them. Specifically, tools and methods were considered important to identify wider, less tangible benefits and services from ecosystems across society, for example cultural services and the value attributed to them. Although stakeholders acknowledged that some tools and methods already existed, the ability to bring together knowledge dispersed across different types of stakeholders and across large geographic areas was identified as a particular need. This related to the need identified by EU level stakeholders to up-scale methods and tools for application across larger areas, including across political boundaries to contribute to transnational coordination for improved environmental management. Conversely, the need for tools and methods to include assessments of regulatory services, which are often the focus of assessments across larger scales, was identified as a need for assessments focusing on smaller areas. Stakeholders also identified the importance of tools to undertake monetary valuation and incorporate the full range of services for this, particularly to influence policy makers. Stakeholders also highlighted the importance of tools for non-monetary valuations and to move beyond the current strong focus on monetary valuation for ecosystem services. This was identified as important to better represent the full range of services and wider stakeholder perspectives in knowledge emerging from processes. This was an important need for a range of stakeholders but particularly for some local non-government organisations and local business stakeholders to better capture less tangible benefits and services, and thus present a more realistic picture of the diversity of benefits, services and values on the ground.

EU policy based stakeholders also identified the need to develop indicators to monitor and evaluate action on the ground. Linked to this was an emphasis on the importance of tools and methods to better understand feedbacks in socio-ecological systems and to help avoid negative impacts and unintended consequences of decisions and actions on the ground. Predominantly this related to the need to gather quantitative data, particularly at the EU level. However more broadly the need for qualitative data was also identified to better integrate different sources and types of knowledge into decision making. This included stakeholders focusing on action at smaller scales, for example the knowledge of local people, and larger scales, although at this scale the need to convert qualitative into quantitative data to inform decision making was emphasised.

Overall, this group of knowledge needs relates to the need for tools and methods that improve integrated approaches in the assessment of ecosystem services across different scales, to involve and inform the decision making of different stakeholder groups. A summary of the knowledge needs relating to tools and methods is provided in table 6.

437 **Table 6: Summary of the knowledge needs relating to tools and methods**

Knowledge needs relating to methods and tools	☐ Provide simple, transparent tools and methods that can be applied across contexts to identify synergies and trade-offs across different spatial and temporal scales to inform decision making
	☐ Develop tools and methods to bring together different types and sources of knowledge to improve the assessment of the supply and demand of the full range of ecosystem services
	☐ Understand the different data and information needs across stakeholder groups (for example, non-monetary valuation may be more relevant for local stakeholders)
	☐ Include a wider range of ecosystem services across the different scales at which assessments of ecosystem services are undertaken (for example, local assessment to transboundary assessments involving more than one European Union Member State)
	☐ Develop quantitative indicators to monitor and evaluate the implementation of ecosystem services across large geographic areas (for example at the EU level)

438

Discussion

440 This study aimed to identify knowledge needs for the operationalisation of ecosystem services across
441 different contexts, involving different sectors, stakeholders and levels of governance. In the
442 analytical process four overarching themes were identified, namely; (i) knowledge needs to develop
443 a common understanding, (ii) knowledge needs on the role of formal and informal institutions in
444 shaping action on the ground, (iii) knowledge needs to link knowledge and action, an (iv) knowledge
445 needs relating to tools and methods. Here the implications of these findings to contribute to the
446 operationalisation of the concept of ecosystem services are explored.

447

Knowledge needs for the operationalisation of the concept of ecosystem services

449 These four themes are interrelated and represent important aspects that require attention to help
450 operationalise the concept of ecosystem services more widely into policy and practice. The
451 importance of developing a common understanding through the selective use of language, with the
452 ideas and meanings attached with this, is widely recognised as critical in the literature focusing on
453 environmental discourse, message framing and science-policy interfaces to help identify shared
454 goals and prime the development of collaborative processes. Specifically, effective communication
455 and translation using the language and experiences of key target stakeholder groups can speed up
456 understanding and identify potential areas of mutual benefit to then move to exploring the
457 application of the concept within a specific context (Cash et al., 2003). In this way selecting and
458 adapting language can help develop more effective arguments to mobilise capacities and share
459 resources (Carmen et al., 2016). Developing a common understanding relates to the knowledge need
460 to develop and apply 'know how' to engage a broad range of stakeholder groups to stimulate their
461 interest in developing collaborations and applying integrated approaches to socio-ecological issues
462 as set out within the ecosystem services concept. This involves knowledge on how to use linguistic,

463 cognitive and technical tools to help change mindsets to develop 'collaborative readiness' (Stokols,
464 2006, Potschin-Young et al., This issue)) for better working across traditional boundaries, for
465 example between science and policy and between policy sectors for more integrated policy
466 development and with practitioners in policy implementation. There is often a strong link between
467 formal institutions such as policy frameworks and the goals of stakeholders in policy and practice
468 based communities. Indeed, analysing current policy frameworks and how they can be strengthened
469 to better align with the concept of ecosystem services is one strand of the current ecosystem
470 services literature, for example see Matzdorf and Meyer (2014). Policy processes are complex
471 involving layers of decisions, stakeholders and their actions (Keeley and Scoones, 1999). Within this
472 process a mismatch between policy rhetoric and practice may develop. Understanding the role of
473 informal institutions in shaping action on the ground is therefore an important knowledge need for
474 operationalising the concept of ecosystem services. This involves norms and cultures of different
475 practitioner groups, that help shape the attitudes and behaviours of stakeholders who may have an
476 important role in turning the concept of ecosystem services into action on the ground, for example
477 local government officers. Importantly attitudes and behaviours that encourage integrated
478 approaches need to be identified and fostered. More specifically, understanding how to move from
479 cooperation, where working together is focused on individual ends, into collaboration, which
480 involves working together for a common goal, is crucial (Jeffrey, 2003). A stronger focus on changing
481 practice for ecosystem services is an essential step towards building practical knowledge, which is
482 embedded in learning through experience to bring the gap between wider goals, attitudes and
483 behaviours closer together (Flyvbjerg, 2001, Boiral, 2002). The concept of ecosystem services
484 involves core principles that emphases a need to adopt integrated approaches and deliver mutual
485 benefits for diverse social groups. The need to foster collaborative thinking and practices implicitly
486 connects these principles and is therefore an important leverage point to help turn this concept into
487 practice more widely.

488 This study has a number of limitations. It is limited in so far as a break-down of knowledge needs
489 across different stakeholder groups, levels of governance and broader socio-ecological context was
490 not possible due to the different levels of engagement of stakeholders across the case studies
491 included in the study and language barriers. Both of these factors meant that data collection was
492 undertaken using both interviews and focus groups which relied on collaboration with the local case
493 study research teams to collect data. Despite the development of data collection protocols this
494 makes a comparative analysis problematic. Instead, the data was combined and broad areas of
495 knowledge needs identified for the ecosystem services community. At the EU level some difference
496 in knowledge needs were identified, for example for collaborating across policy sectors, consistency
497 in data, methods and monitoring across large geographic areas and political boundaries. However,
498 more interestingly, there are subtle differences in the orientation between the four themes
499 identified in this study, not only about types of knowledge need, but also whose knowledge.
500 Whereas developing a common understanding relates to the ecosystem services community working
501 with other stakeholder groups, the role of formal and informal institutions predominately focuses
502 attention towards knowledge for and by science and practice. The need to develop tools and
503 methods and the need to link knowledge and action however predominantly focuses on knowledge
504 needs from specifically within the ecosystem services scientific community. Together these four
505 interrelated themes mirrors a broad perspective of knowledge as a multidimensional, dynamic
506 process. However, addressing these knowledge needs may help provide more credence to the
507 importance of considering an understanding of socio-ecological in decision making processes, these
508 processes are complex and dynamic and may be influenced by a range of other factors. These
509 knowledge needs may be necessary but insufficient to fully operationalise the concept of ecosystem
510 services into action on the ground.

511

Contribution from the ecosystem services scientific community to better operationalise the concept

514 There is a growing recognition in scientific communities of the importance of developing knowledge
515 that is legitimate, for example by including wider stakeholders, and relevant to provide knowledge to
516 more readily feed into decision making in policy communities (Sarkki et al., 2013, Carmen et al.,
517 2015). In relation to ecosystem services this has often focused on two key areas. The first is the
518 development of methods, frameworks, models and tools to better capture and therefore understand
519 the dynamics of issues. Increasingly these are being used to recognize a range of perspectives of
520 different stakeholder groups. This knowledge need for the development of tools and methods
521 relates to improving technical capacity, or 'know-how', to apply these to help understand the
522 dynamics of issues in different contexts, leading to explicit knowledge products, such as
523 environmental assessments, that focus on 'know why' (Flyvbjerg, 2001). Secondly more recently
524 research has begun to more explicitly focus on informing policy development at larger scales at the
525 national, European and global levels and bring knowledge and action closer together, for example
526 through the Intergovernmental Platform for Biodiversity and Ecosystem Services (Koetz et al., 2012).
527 More widely therefore discussions are turning towards a need to develop and apply *Mode 2*
528 knowledge processes to better influence decision making across levels of governance. Despite this,
529 there has been very little attention in the ecosystem service literature to date focusing on the need
530 for more inclusive, collaborative approaches more broadly that orientate to both knowledge
531 production *and* action. In the sustainability science literature however there has been a growing
532 discussion about the need to apply more collaborative transdisciplinary research approaches that
533 take place within real life situations and actively engage in the messy realities of helping to facilitate
534 change (Brandt et al., 2013). Specifically this involves teams of stakeholders from science and policy/
535 practice developing processes for mutual benefit that actively bring together different sources of
536 knowledge and perspectives to develop solutions to real world problems. Transdisciplinary research
537 not only promises to help better understand problems and potential solutions across contexts, but
538 also invitingly encapsulates the potential to more readily facilitate change across different social
539 settings.

540 The transdisciplinary literature broadly encompasses terms such as co-production of knowledge and
541 action-research (Lang et al., 2012, Wyborn, 2015a, Checkland and Holwell, 1998, Cameron and
542 Gibson, 2005). Transdisciplinarity is emerging as a research topic in its own right and this has helped
543 stimulate critical examination at conceptual, methodological and practical level (Rosendahl et al.,
544 2015, Klay et al., 2015, Lang et al., 2012). At a conceptual level transdisciplinary research embraces
545 an interactional model of knowledge production, involving collaborations between scientists from
546 different disciplines and non-academic stakeholders to create solution orientated knowledge that is
547 socially robust and can be applied to both scientific and societal practice (Stokols, 2006). Conversely,
548 inter disciplinary research crosses disciplinary boundaries within scientific communities to produce
549 knowledge (Lyall et al., 2015). Methodologically, transdisciplinary research has been linked to
550 poststructuralism in so far as it recognises multiple types of knowledge as equally valid (Cameron
551 and Gibson, 2005). The design of such research processes has also been connected to a broader
552 form of experimental design (Moses and Knutsen, 2012). Critical however is the iterative coupling
553 between knowledge production and integration into action orientated process through reflective
554 practice in the process. Specifically, for the concept of ecosystem services this could involve specific
555 coupling with, exploring and learning about decision making processes across different levels.
556 Practically, a number of principles have been outlined to guide the development of transdisciplinary
557 research processes. This involve the importance of the composition of the research team, which

558   should involve scientific and non-scientific stakeholders to foster collaborative working and feedback
559   from the start. Lang et al. (2012) outline three critical phases of transdisciplinary research. The first
560   phase is collaboratively framing the problem to identify a shared goal and shape the research
561   questions. At the same time this helps develop a common understanding about language, capacities
562   and perspectives within the team (Cash et al., 2003, Jeffrey, 2003). The second phase is coproduction
563   of solution oriented knowledge by applying collaborative research practices and methods. The third
564   phase focuses on the re-integration of knowledge, involving tangible outputs and less tangible
565   learning outcomes emerging from the process. This re-integration is orientated towards decision
566   making, action and practice however also provides opportunities to reveal gaps in knowledge and
567   also continue to develop scientific practice.

568   An important component of any knowledge production process is the use and development of
569   methods, tools, techniques, frameworks and models. Critically these need to be aligned with the
570   research approach and design. Thus in transdisciplinary research approaches methods and tools
571   need to be explicitly developed for and applied as boundary objects, for example to bring
572   stakeholders and their knowledge together to jointly examine an issue, identify patterns, links and
573   gaps for the assessment and valuation of ecosystem services. Star and Griesemer (1989) defined a
574   boundary object as an artefact, for example a tool or framework, that is adaptable to different needs
575   and perspectives yet robust enough to maintain a common identify across different contexts and
576   scales. In this way boundary objects explicitly facilitate collaborative action orientated research
577   processes by helping to bridge ontological and epistemological boundaries between different groups
578   of stakeholders, issues and scales (Keshkamat et al., 2012, Brand and Jax, 2007). There is a strong
579   focus on the use and development of frameworks, method and tools in the ecosystem services
580   literature with the aim of continuing to improve knowledge presented in assessments across scales
581   (Nelson et al., 2009, Daily et al., 2009, Rodríguez-Loinaz et al., 2015). Nonetheless, there is often very
582   little critical discussion about the research approaches and assumptions that shape the context
583   within which tools are applied and the outcomes that emerge from them more broadly. This critical
584   reflection is an important part of ensuring tools and methods operate and maximise their potential
585   to be boundary objects in practice. More importantly however this can help move beyond dominant
586   perspectives in scientific ecosystem services communities that primarily view stakeholders and their
587   involvement in research processes purely as sources of data.

588   Widely recognised in the transdisciplinary research literature is how challenging it is to apply these
589   approaches in practice. This relates to both formal and informal institutional constraints. Examples
590   of formal institutional constraints includes a research system that still often approaches the
591   processes of knowledge production, exchange and integration as separate (Stokols, 2006).
592   Transdisciplinary research with a specific framing around the concept of ecosystem services also face
593   structural constraints in working with and bringing together a range of practitioners organised
594   around separate policy areas. Additional, informal institutional constraints also exist in both science
595   and practice orientated communities. Specifically this involves norms, attitudes and behaviours that
596   shape the type of relationships developed over time, for example across science-policy/ practice
597   interfaces and the move from cooperation to more meaningful collaborative practices. Formal
598   institutions can help develop spaces to bring different groups together, however these often focus
599   on specific issues and values (Wyborn and Bixler, 2013). A critical need therefore for scientific
600   stakeholders is to focus on developing relationships and trust across groups of stakeholders and to
601   develop the capacity, or 'know how', within ecosystem services scientific teams to collaborative
602   more broadly and more effectively around the issue of ecosystem services. For scientific
603   communities to contribute to the operationalisation of ecosystem services an important aspect of
604   this is developing an understanding about, experience of and skills to contribute to and shape
605   transdisciplinary research processes to develop action-orientated outcomes to facilitate change and

606 mutual learning outcomes (Van Kerkhoff and Lebel, 2015). For the ecosystem services science
607 community the knowledge needs highlighted in this study therefore broadly relate to two interlinked
608 objectives: to turn the concept of ecosystem services into practice and to develop transdisciplinary
609 research approaches and practice. **Conclusions**

610 At the heart of the ecosystem services concept is the core principle of applying an integrated
611 approach to better shape our understanding of and actions around ecosystems and the services they
612 provide to human society. This requires collaborative, multi-stakeholder processes and practices.
613 The current focus across much of the ecosystem services literature is concerned with examining
614 impacts and identifying constraints. There is a real need for science to not only observe change but
615 also understand and engage in change processes more actively (Daily et al., 2009). Transdisciplinary
616 research approaches provides a promising opportunity for the ecosystem services science
617 community itself to embrace the core principle of integration embedded within the concept whilst
618 contributing to the operationalisation of this concept more broadly. A greater orientation towards
619 transdisciplinary research processes in the ecosystem services science community requires engaging
620 in the messy realities of real world socio-ecological problems, involving different combinations of
621 stakeholder, perspectives, practices, tools and structural constraints. Science is predicated on its
622 ability to critically build on existing knowledge (Klay et al., 2015). Only by actively engaging in
623 transdisciplinary research processes will the ecosystem services science community begin to develop
624 the experience and, more importantly the knowledge about how to more effectively collaborative
625 with diverse stakeholder groups, apply integrated approaches across contexts, bring knowledge and
626 action together and facilitate change in practice.

Acknowledgements

References

637 ADAMS, W. M. & SANDBROOK, C. 2013. Conservation, evidence and policy. *Oryx,* 47**,** 329-335.
638 ARKSEY, H. & KNIGHT, P. 1999. Why Interview? *Interviewing for social scientists : an introductory*
639   *resource with examples.* London: Sage.
640 ARMITAGE, D. R., PLUMMER, R., BERKES, F., ARTHUR, R. I., CHARLES, A. T., DAVIDSON-HUNT, I. J.,
641   DIDUCK, A. P., DOUBLEDAY, N. C., JOHNSON, D. S., MARSCHKE, M. & MCCONNEY, P. 2009.
642   Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the*
643   *Environment,* 7**,** 95-102.
644 BAGSTAD, K. J., SEMMENS, D. J., WAAGE, S. & WINTHROP, R. 2013. A comparative assessment of
645   decision-support tools for ecosystem services quanitification and valuation. *Ecosystem*
646   *Services,* 5**,** 27-39.
647 BENGT, J. 2011. Towards a practice theory of entrepreneuring. *Small Business Economics,* 36**,**
648   135150.
649 BERKES, F., COLDING, J. & FOLKE, C. 2000. Rediscovery of traditional ecological knowledge as
650   adpative management. *Ecological applications,* 10**,** 1251-1262.

651 BOIRAL, O. 2002. Tactic knowledge and environmental management. *Long Range Planning,* 35**,**
652   291317.
653 BRAAT, L. C. & DE GROOT, R. 2012. The ecosystem services agenda: bridging the worlds of natural
654   science and economics, conservation and development, and public and private policy.
655   *Ecosystem Services,* 1**,** 4-15.
656 BRAND, S. F. & JAX, K. 2007. Focusing the meaning(s) of resilience: Resileience as a descriptive
657   concept and a boundary object. *Ecology and Society,* 12**,** 23.
658 BRANDT, P., ERNST, A., GRALLA, F., LUEDERITZ, C., LANG, D. J., NEWIG, J., REINERT, F., ABSON, D. J. &
659   VON WEHRDEN, H. 2013. A review of transdisciplinary research in sustainability science.
660   *Ecological Economics,* 92**,** 1-15.
661 BRYMAN, A. 2004. *Social Research Methods,* Oxford, New York, Oxford University Press.
662 BRYMAN, A. 2016. *Social research methods,* Oxford, UK, Oxford University Press.
663 BUIZER, M., ARTS, B. & KOK, K. 2011. Governance, scale and the environment: the importance of
664   recognizing knowledge claims in transdisciplinary arenas. *Ecology and Society,* 16.
665 CAMERON, J. & GIBSON, K. 2005. Participatory action research in a poststructuralist vein. *Geoforum,*
666   36**,** 315-331.
667 CARMEN, E., NESSHÖVER, C., SAARIKOSKI, H., VANDEWALLE, M., WATT, A., WITTMER, H. & YOUNG,
668   J. 2015. Creating a biodiversity science community: Experiences from a European Network of
669   Knowledge. *Environmental Science & Policy*.
670 CARMEN, E., WATT, A. & YOUNG, J. 2016. Arguing for biodiversity in practice from the national to the
671   local: A case from the UK *Biodiversity and Conservation*.
672 CARPENTER, S. R., MOONEY, H. A., AGARD, J., CAPISTRANO, D., DEFRIES, R. S., DÍAZ, S., DIETZ, T.,
673   DURAIAPPAH, A. K., OTENG-YEBOAH, A., PEREIRA, H. M. & PERRINGS, C. 2009. Science for
674   managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings*
675   *of the National Academy of Sciences of the United States of America,* 106**,** 1305-1312.
676 CASH, D. W., CLARK, W. C., ALCOCK, F., DICKSON, N. M., ECKLEY, N., GUSTON, D. H., JAGER, J. &
677   MITCHELL, R. B. 2003. Knowledge systems for sustainable development. *Proceedings of the*
678   *National Academy of Sciences of the United States of America,* 100**,** 8086-8091.
679 CHECKLAND, P. & HOLWELL, S. 1998. Action Research: Its nature and validity. *Systematic Practice*
680   *and Action Research,* 11**,** 9-21.
681 CORNELL, S. 2011. The rise and rise of ecosystem services: Is "value" the best bridging concept
682   between society and the natural world? *Procedia Environmental Sciences,* 6**,** 88-95.
683 CUNDILL, G., CUMMING, G. S., BIGGS, D. & FABRICIUS, C. 2012. Soft systems thinking and social
684   learning for adaptive management. *Conservation Biology,* 26**,** 13-20.
685 DAILY, G. C., POLASKY, S., GOLDSTEIN, J., KAREIVA, P. M., MOONEY, H. A., PEJCHAR, L., RICKETTS, T.
686   H., SALZMAN, J. & SHALLENBERGER, R. 2009. Ecosystem services in decision making: time to
687   deliver. *Frontiers in Ecology and the Environment,* 7**,** 21-28.
688 DE GROOT, R. S., ALKEMADE, R., BRAAT, L., HEIN, L. & WILLEMEN, L. 2010. Challenges in integrating
689   the concept of ecosystem services and values in landscape planning, management and
690   decision making. *Ecological complexity,* 7**,** 260-272.
691 DICK, J., TURKELBOOMB, F., WOODS, H., INIESTA-ARANDIA, I., PRIMMER, E., SAARELA, S., BEZÁK, P.,
692   MEDERLY, P., LEONE, M., VERHEYDEN, W., KELEMENG, E., HAUCK, J., ANDREWS, C.,
693   ANTUNES, P., ASZALÓS, R., BARÓM, F., BARTON, D. N., BERRY, P., BUGTER, R., CARVALHO, L.,
694   CZÚCZL, B., DUNFORDO, R., GARCIA BLANCO, G., GEAMĂNĂ, N., GIUCĂ, R., GRIZZETTI, B.,
695   IZAKOVIČOVÁ, Z., KERTÉSZ, M., KOPPEROINEN, L., LANGEMEYER, J., MONTENEGRO
696   LAPOLAW, D., LIQUETE, C., LUQUE, S., MARTÍNEZ PASTUR, G., MARTIN-LOPEZ, B.,
697   MUKHOPADHYAYA, R., NIEMELAA, Y., ODEE, D., LUIS PERIAD, P., PINHOA, P.,
698   PATRÍCIOROBERTO, G. B., PREDA, E., PRIESS, J., RÖCKMANNA, C., SANTOS, R., SILAGHIA, D.,
699   SMITH, R.,

700   VĂDINEANU, A., TJALLING VAN DER WALA, J., ARANY, I., BADEA O., BELAG, G., BOROS, E.,
701   BUCUR, M., BLUMENTRATH, S., CALVACHE, M., CARMEN, E., CLEMENTE, P., FERNANDES, J.,
702   FERRAZ, D., FONGARA, C., GARCÍA-LLORENTE, M., GÓMEZ-BAGGETHUN, E., GUNDERSEN, V.,
703   HAAVARDSHOLM, O., KALÓCZKAI, A., KHALALWE, T., KISS, G., KÖHLER B., LAZÁNYI, O.,
704   LELLEI-KOVÁCS, E., LICHUNGU, R., LINDHJEM, H., MAGARE, C., MUSTAJOKI, J., NDEGE, C.,
705   NOWELL, M., NUSS GIRONA, S., OCHIENG, J., OFTEN, A., PALOMO, I., PATAKI, G., REINVANG,
706   R., RUSCH, G., SAARIKOSKI, H., SMITH, A., SOY MASSONI, E., STANGE, E., VÅGNES TRAAHOLT,
707   N., VÁRI, A., VERWEIJ, P., VIKSTRÖM, S., YLI-PELKONEN, V. & ZULIAN, G. (This issue)
708   Stakeholders' perspectives on the operationalisation of ecosystem services concept: results
709   from 27 case studies. *Ecosystem Services.*
710 FAILING, L., GREGORY, R. & HARSTONE, M. 2007. Integrating science and local knowledge in
711   environmental risk management: A decision focused approach. *Ecological Economics,* 64**,**
712   4760.
713 FAZEY, I., BUNSE, L., MSIKA, J., PINKE, M., PREEDY, K., EVELY, A. C., LAMBERT, E., HASTINGS, E.,
714   MORRIS, S. & REED, M. S. 2014. Evaluating knowledge exchange in interdisciplinary and
715   multi-stakeholder research. *Global Environmental Change,* 25**,** 204-220.
716 FAZEY, I., FAZEY, J. A., SALISBURY, J. G., LINDENMAYER, D. B. & DOVERS, S. 2006. The nature and role
717   of experiential knowledge for environmental conservation. *Environmental Conservation,* 33**,**
718   1-10.
719 FISHER, B., TURNER, R. K. & MORLING, P. 2009. Defining and classifying ecosystem services for
720   decision making. *Ecological Economics,* 68**,** 643-653.
721 FLYVBJERG, B. 2001. *Making social science matter: Why social inquiry fails and how it can succeed*
722   *again,* Cambridge, UK, Cambridge University Press.
723 HANNIGAN, J. 1995. *Environmental Sociology,* Abingdon, Routledge.
724 HAUCK, J., GORG, C., VARJOPURO, R., RATAMKI, O. & JAX, K. 2013. Benefits and limittions of the
725   ecosystem services concept in environmental policy and decision making: Some stakeholder
726   perspectives. *Environmental Science & Policy,* 25**,** 13-21.
727 JAX, ET AL. (this issue) The OpenNESS approach - from real world problems to concepts and back to
728   real world solutions - the nexus thinking. *Ecosystem Services.*
729 JEFFREY, P. 2003. Smoothing the waters: Observations on the process of cross-dsiciplinary research
730   collaboration. *Social Studies of Science,* 33**,** 539-562.
731 KEELEY, J. & SCOONES, I. 1999. *Understanding environmental policy process: a review,* Brighton UK,
732   Institute of Development Studies.
733 KESHKAMAT, S. S., KOOIMAN, A., VAN MAARSEVEEN, M. F. A. M., VAN DER VEEN, A. & ZUIDGEEST,
734   M. H., P., 2012. A boundary object for scale selection - moderating differences and
735   synergising understanding. *Ecological Economics,* 76**,** 15-24.
736 KLAY, A., ZIMMERMANN, A. B. & SCNEIDER, F. 2015. Rethinking science for sustainable development:
737   Reflexive interaction for paradigm transformation. *Futures,* 65**,** 72-85.
738 KOETZ, T., FARRELL, K. N. & BRIDGEWATER, P. 2012. Building better science-policy interfaces for
739   international environmental governance: assessing potential within the Intergovernmental
740   Platform for Biodiversity and Ecosystem Services. *International Environmental*
741   *AgreementsPolitics Law and Economics,* 12**,** 1-21.
742 LANG, D. J., WIEK, A., BERGMANN, M., STAUFFACHER, M., MARTENS, P., MOLL, P., SWILLING, M. &
743   THOMAS, C. J. 2012. Transdisciplinary research in sustainability science: practice, principles,
744   and challenges. *Sustainability science,* 7**,** 25-43.
745 LEJANO, R. P. & INGRAM, H. 2009. Collaborative networks and new ways of knowing. *Environmental*
746   *Science & Policy,* 12**,** 653-662.
747 LEMOS, C. M. & MOREHOUSE, B. J. 2005. The co-production of science and policy in integrated
748   cliamte assessments. *Global Environmental Change,* 15**,** 57-68.

749 LUEDERITZ, C., BRINK, E., GRALLA, F., HERMELINGMEIER, V., MEYER, M., NIVEN, L., PANZER, L.,
750   PARTELOW, S., RAU, A. L., SASAKI, R. & ABSON, D. J. 2015. A review of urban ecosystem
751   services: six key challenges for future research. *Ecosystem Services,* 14**,** 98-112.
752 LUKS, F. & SIEBENHUNER, B. 2007. Transdisciplinarity for social learning? The contribution of the
753   German socio-ecological research initiative to sustainability governance. *Ecological*
754   *Economics,* 63**,** 418-426.
755 LYALL, C., MEAGHER, L. & BRUCE, A. 2015. A rose by any other name? Transdisciplinarity in th conxet
756   of UK research policy. *Futures,* 65**,** 150-162.
757 MACE, G., NORRIS, K. & FITTER, A. 2012. Biodiversity and ecosystem services: A multilayered
758   relationship. *Trends in Ecology and Evolution,* 27**,** 19-26.
759 MASON, J. 2002. *Qualitative Researching,* London, Thousand Oaks, Singapore, Sage.
760 MATZDORF, C. & MEYER, C. 2014. The relevance of the ecosystem services framework for the
761   developed countries environmenatl policies: A compartive case study of the US and EU. *Land*
762   *Use Policy,* 38**,** 509-521.
763 MILES, M. B. & HUBERMAN, M. A. 1994. Making good sense. *In:* MILES, M. B. (ed.) *Qualitative data*
764   *analysis: an expanded sourcebook.* London: Sage.
765 MORGAN, D. L. 1996. Focus groups. *Annual Review of Sociology,* 22**,** 129-152.
766 MOSES, J. W. & KNUTSEN, T. L. 2012. *Ways of knowing: Competing methodologies in social and*
767   *political research: Second edition,,* Basingstoke, UK,, Palgrave McMillian.
768 NELSON, E., MENDOZA, G., REGETZ, J., POLASKY, S., TALLIS, H., CAMERON, D., CHAN, K., DAILY, G. C.,
769   GOLDSTEIN, J., KAREIVA, P. M. & LONSDORF, E. 2009. Modeling multiple ecosystem services,
770   biodiversity conservation, commodity production, and tradeoffs at landscape scales.
771   *Frontiers in Ecology and the Environment,* 7**,** 4-11.
772 NUTLEY, S. M., WALTER, I. & DAVISE, H. T. O. 2007. *Using evidence: How research can inform public*
773   *services,* Bristol, UK, ThePolicy Press.
774 PAHL-WOSTL, C. 2009. A conceptual framework for analysing adapative capacity and multi-level
775   learning process in resources governance regimes. *Global Environmental Change,* 19**,**
776   354365.
777 PAWSON, R., WONG, G. & OWEN, L. 2011. Known knowns, known unknowns, unknown unknowns:
778   The predicament of evidence-based policy. *American Journal of Evalutaion,* 32.
779 PLUMMER, R. & ARMITAGE, D. 2007. A resilience-based framework for evaluating adaptive
780   comanagement: linking ecology, economics and society in a complex world. *Ecological*
781   *Economics,* 61**,** 62-74.
782 PLUMMER, R. & HASHIMOTO, A. 2011. Adaptive co-management and the need for situated thinking
783   in collaborative conservation. *Human Dimensions of Wildlife,* 16**,** 222-235.
784 POTSCHIN-YOUNG, M., HAINES-YOUNG, R. H., GÖRG, C., HEINK, U., JAX, K. & SCHLEYER, C. (This
785   issue) Understanding the role of conceptual frameworks: Reading the ecosystem services
786   cascade. *Ecosystem Services.*
787 PRAGER, K., REED, M. & SCOTT, A. 2012. Encouraging collaboration for the provision of ecosystem
788   services at a landscape scale—rethinking agri-environmental payments. *Land Use Policy,* 29.
789 RODRÍGUEZ-LOINAZ, G., ALDAY, J. G. & ONAINDIA, M. 2015. Multiple ecosystem services landscape
790   index: a tool for multifunctional landscapes conservation. *Journal of Environmental*
791   *Management,* 147**,** 152-163.
792 ROSENDAHL, J., ZANELLA, M. A., RIST, S. & WEIGELT, J. 2015. Scientists' situated knowledge: Strong
793   objectivity in transdisciplinarity. *Futures,* 65**,** 17-27.
794 RYAN, G. W. & BERNARD, H., R., 2003. Techniques to identify themes. *Field methods,* 15**,** 85-109.
795 SARKKI, S., NIEMELA, J., TINCH, R., VAN DEN HOVE, S., WATT, A. & YOUNG, J. 2013. Balancing
796   credibility, relevance and legitimacy: A critical assessment of trade-offs in science-policy
797   interfaces. *Science and Public Policy*.

798   SHOTTER, J. & TSOUKAS, H. 2014. Performing phronesis: On the way to engage judgement.
799   *Management Lerning,* 45.
800   STAR, S. L. & GRIESEMER, J. R. 1989. Institutional ecology, 'translations' and boundary objects:
801   amateurs and professionals in Berkeleys's museum of vertebrate zoology. *Social Studies of*
802   *Science,* 19**,** 387-420.
803   STOKOLS, D. 2006. Towards a science of transdisciplinary action research. *American Journal of*
804   *Community Psychology,* 38**,** 63-77.
805   STRAUSS, A. & CORBIN, J. 1990. *Basics of qualitative research: Grounded theory procedures and*
806   *techniques*, Sage.
807   STRINGER, L., DOUGILL, A., FRASER, E., HUBACEK, K., PRELL, C. & REED, M. 2006. Unpacking
808   "participation" in the adaptive management of social–ecological systems: a critical review.
809   *Ecology and Society,* 11, 2.
810   VAN KERKHOFF, L. E. & LEBEL, L. 2015. Coproduction capacities: Rethinking science-governance
811   relations in a diverse world. *Ecology and Society,* 20.
812   VINK, M. J., DEWULF, A. & TERMEER, C. 2013. The role of knowledge and power in climate change
813   adapation governance: a systematic literature review. *Ecology and Society,* 18**,** 46.
814   WAYLEN, K. A. & YOUNG, J. 2014. Expectations and experieces of diverse forms of knowledge use:
815   the case of the UK National Ecosystem Assessment. *Environment and Planning CGovernment*
816   *and Policy,* 32**,** 229-246.
817   WIEK, A., NESS, B., SCHWEIZER-REIS, P., BRAND, F. S. & FARIOLI, F. 2012. From complex systems
818   analysis to trasnformational change: A comparative appraisal of sustainability science
819   projects. *Sustain Sci,* 7**,** 5-24.
820   WYBORN, C. 2015a. Co-productive governance: A relational framework for adaptive governance.
821   *Global Environmental Change,* 30 56-67.
822   WYBORN, C. 2015b. Cross-Scale Linkages in Connectivity Conservation: Adaptive governance
823   challenges in spatially distributed networks. *Environmental Policy and Governance,* 25**,** 1-15.
824   WYBORN, C. & BIXLER, P. R. 2013. Collaboration and nested environmental governance: Scale
825   dependency, scale framing and cross scale-interactions in collaborative conservation. *Journal*
826   *of Environmental Management,* 123**,** 58-67.
827   YOUNG, J. C., WAYLEN, K. A., SARKKI, S., ALBON, S., BAINBRIDGE, I., BALIAN, E., DAVIDSON, J.,
828   EDWARDS, D., FAIRLEY, R., MARGERISON, C., MCCRACKEN, D., OWEN, R., QUINE, C. P.,
829   STEWART-ROPER, C., THOMPSON, D., TINCH, R., VAN DEN HOVE, S. & WATT, A. 2014.
830   Improving the science-policy dialogue to meet the challenges of biodiversity conservation:
831   having conversations rather than talking at one-another. *Biodiversity and Conservation,* 23**,**
832   387-404.