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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

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

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									
EU				✓		✓	✓	✓	✓
National		✓		✓		✓	✓	✓	
Regional		✓	✓	✓	✓	✓	✓		
Local	✓	✓	✓		✓	✓		✓	
Governance focus									
Legal	✓	✓		✓				✓	
Administrative	✓	✓	✓	✓			✓		✓
Political	✓			✓					
Planning	✓	✓			✓	✓			
Policy sector									
Agriculture		✓		✓	✓	✓			✓
Forestry				✓	✓	✓			✓
Freshwater						✓	✓	✓	
Urban	✓	✓	✓			✓	✓		
Protected area					✓	✓		✓	✓
Wildlife					✓			✓	✓
Bio-energy				✓					

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

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

Focus group discussions were used to gather data with EU level stakeholders and from six of the nine case studies. Semi structured interviews were used in combination with focus groups in three of these six case studies. This combination of methods was used with stakeholders with higher levels of engagement in the cases study who spoke a language other than English. It involved the case study research leaders coordinating and facilitating the focus group discussion in the native language of the stakeholders and feeding back issues discussed and exploring their own views and perspectives on knowledge needs through semi structured interviews. In a further three case studies semi structured interviews with case study coordinator team members were used to collect data when it was to not possible to bring together a group of stakeholders, which is an essential requirement for the focus group methodology (Morgan, 1996).

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

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

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

Results

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

Knowledge needs to develop a common understanding

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

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

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

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

Overall developing a common understanding was identified as an overarching knowledge need to contribute to the operationalising the concept of ecosystem services by helping to bring together and facilitate dialogue between different stakeholder groups, across different contexts as an important first step towards collaborative working to addresses context specific needs. A summary of the knowledge needs to contribute towards developing a common understanding is provided in table 3.

Table 3: Summary of the knowledge needs to develop a common understanding between different 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

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

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

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

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

Table 4: Summary of the knowledge needs on the role of formal and informal institutions in 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

Knowledge needs to link knowledge and action

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

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

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

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

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

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

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

Knowledge needs to 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

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.

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)

Discussion

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

Knowledge needs for the operationalisation of the concept of ecosystem services

These four themes are interrelated and represent important aspects that require attention to help operationalise the concept of ecosystem services more widely into policy and practice. The importance of developing a common understanding through the selective use of language, with the ideas and meanings attached with this, is widely recognised as critical in the literature focusing on environmental discourse, message framing and science-policy interfaces to help identify shared goals and prime the development of collaborative processes. Specifically, effective communication and translation using the language and experiences of key target stakeholder groups can speed up understanding and identify potential areas of mutual benefit to then move to exploring the application of the concept within a specific context (Cash et al., 2003). In this way selecting and adapting language can help develop more effective arguments to mobilise capacities and share resources (Carmen et al., 2016). Developing a common understanding relates to the knowledge need to develop and apply 'know how' to engage a broad range of stakeholder groups to stimulate their interest in developing collaborations and applying integrated approaches to socio-ecological issues as set out within the ecosystem services concept. This involves knowledge on how to use linguistic, cognitive and technical tools to help change mindsets to develop ‘collaborative readiness’ (Stokols, 2006, Potschin-Young et al., This issue)) for better working across traditional boundaries, for example between science and policy and between policy sectors for more integrated policy development and with practitioners in policy implementation. There is often a strong link between formal institutions such as policy frameworks and the goals of stakeholders in policy and practice based communities. Indeed, analysing current policy frameworks and how they can be strengthened to better align with the concept of ecosystem services is one strand of the current ecosystem services literature, for example see Matzdorf and Meyer (2014). Policy processes are complex involving layers of decisions, stakeholders and their actions (Keeley and Scoones, 1999). Within this process a mismatch between policy rhetoric and practice may develop. Understanding the role of informal institutions in shaping action on the ground is therefore an important knowledge need for operationalising the concept of ecosystem services. This involves norms and cultures of different practitioner groups, that help shape the attitudes and behaviours of stakeholders who may have an important role in turning the concept of ecosystem services into action on the ground, for example local government officers. Importantly attitudes and behaviours that encourage integrated approaches need to be identified and fostered. More specifically, understanding how to move from cooperation, where working together is focused on individual ends, into collaboration, which involves working together for a common goal, is crucial (Jeffrey, 2003). A stronger focus on changing practice for ecosystem services is an essential step towards building practical knowledge, which is embedded in learning through experience to bring the gap between wider goals, attitudes and behaviours closer together (Flyvbjerg, 2001, Boiral, 2002). The concept of ecosystem services involves core principles that emphases a need to adopt integrated approaches and deliver mutual benefits for diverse social groups. The need to foster collaborative thinking and practices implicitly connects these principles and is therefore an important leverage point to help turn this concept into practice more widely.

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

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

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

The transdisciplinary literature broadly encompasses terms such as co-production of knowledge and action-research (Lang et al., 2012, Wyborn, 2015a, Checkland and Holwell, 1998, Cameron and Gibson, 2005). Transdisciplinarity is emerging as a research topic in its own right and this has helped stimulate critical examination at conceptual, methodological and practical level (Rosendahl et al., 2015, Klay et al., 2015, Lang et al., 2012). At a conceptual level transdisciplinary research embraces an interactional model of knowledge production, involving collaborations between scientists from different disciplines and non-academic stakeholders to create solution orientated knowledge that is socially robust and can be applied to both scientific and societal practice (Stokols, 2006). Conversely, inter disciplinary research crosses disciplinary boundaries within scientific communities to produce knowledge (Lyall et al., 2015). Methodologically, transdisciplinary research has been linked to poststructuralism in so far as it recognises multiple types of knowledge as equally valid (Cameron and Gibson, 2005). The design of such research processes has also been connected to a broader form of experimental design (Moses and Knutsen, 2012). Critical however is the iterative coupling between knowledge production and integration into action orientated process through reflective practice in the process. Specifically, for the concept of ecosystem services this could involve specific coupling with, exploring and learning about decision making processes across different levels. Practically, a number of principles have been outlined to guide the development of transdisciplinary research processes. This involve the importance of the composition of the research team, which should involve scientific and non-scientific stakeholders to foster collaborative working and feedback from the start. Lang et al. (2012) outline three critical phases of transdisciplinary research. The first phase is collaboratively framing the problem to identify a shared goal and shape the research questions. At the same time this helps develop a common understanding about language, capacities and perspectives within the team (Cash et al., 2003, Jeffrey, 2003). The second phase is coproduction of solution oriented knowledge by applying collaborative research practices and methods. The third phase focuses on the re-integration of knowledge, involving tangible outputs and less tangible learning outcomes emerging from the process. This re-integration is orientated towards decision making, action and practice however also provides opportunities to reveal gaps in knowledge and also continue to develop scientific practice.

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

Widely recognised in the transdisciplinary research literature is how challenging it is to apply these approaches in practice. This relates to both formal and informal institutional constraints. Examples of formal institutional constraints includes a research system that still often approaches the processes of knowledge production, exchange and integration as separate (Stokols, 2006). Transdisciplinary research with a specific framing around the concept of ecosystem services also face structural constraints in working with and bringing together a range of practitioners organised around separate policy areas. Additional, informal institutional constraints also exist in both science and practice orientated communities. Specifically this involves norms, attitudes and behaviours that shape the type of relationships developed over time, for example across science-policy/ practice interfaces and the move from cooperation to more meaningful collaborative practices. Formal institutions can help develop spaces to bring different groups together, however these often focus on specific issues and values (Wyborn and Bixler, 2013). A critical need therefore for scientific stakeholders is to focus on developing relationships and trust across groups of stakeholders and to develop the capacity, or ‘know how’, within ecosystem services scientific teams to collaborative more broadly and more effectively around the issue of ecosystem services. For scientific communities to contribute to the operationalisation of ecosystem services an important aspect of this is developing an understanding about, experience of and skills to contribute to and shape transdisciplinary research processes to develop action-orientated outcomes to facilitate change and mutual learning outcomes (Van Kerkhoff and Lebel, 2015). For the ecosystem services science community the knowledge needs highlighted in this study therefore broadly relate to two interlinked objectives: to turn the concept of ecosystem services into practice and to develop transdisciplinary research approaches and practice.

Conclusions

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

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