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Identifying and assessing the application of ecosystem services approaches in environmental policies and decision-making**

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ABSTRACT

The presumption is that ecosystem services (ES) approaches provide a better basis for environmental decision-making than other approaches because they make explicit the connection between human well-being and ecosystem structures and processes. However, the existing literature does not provide a precise description of ES approaches for environmental policy and decision-making, nor does it assess whether these applications will make a difference in terms of changing decisions and improving outcomes.

We describe three criteria that can be used to identify whether and to what extent ES approaches are being applied: connect impacts all the way from ecosystem changes to human well-being; consider all relevant ES affected by the decision; consider and compare the changes in well-being of different stakeholders. As a demonstration, we then analyse retrospectively if and how the criteria were met in different decision-making contexts. For this assessment, we have developed an analysis format that describes the type of policy, the relevant scale(s), the decisions or questions, the decision-maker and the underlying documents. This format includes a general judgement of how far the three ES criteria have been applied. It shows that the criteria can be applied to many different decision-making processes, ranging from the supranational to the local scale and to different parts of decision-making processes.

In conclusion we suggest these criteria could be used for assessments of the extent to which ES approaches have been and should be applied, what benefits and challenges arise, and whether using ES approaches made a difference in the decision-making process, decisions made, or outcomes of those decisions. Results from such studies could inform future use and development of ES approaches, draw attention to where the greatest benefits and challenges are, and help to target integration of ES approaches into policies, where they can be most effective.

Keywords: environmental management, environmental policy, human well-being, stressors

INTRODUCTION

Inspired by the powerful vision of the Millennium Ecosystem Assessment report (MA 2005) Daily et al. (2009) recognised the potential of ecosystem services (ES) approaches as a framework for environmental policy and decision-making processes. However, to realize that potential, they called for rapid advancement in the science behind ES approaches and a systematic integration of ES approaches into decision-making. The presumption is that ES approaches provide a better basis for environmental decision-making than other approaches because they make the connection between human well-being and ecosystem structures and processes explicit.

The ES concept is increasingly used in decision-making instruments and it is used in many different ways. Efforts to develop ES approaches began in the 1990s (Bingham et al. 1995) but have increased recently (e.g. Fisher et al. 2009; De Groot et al. 2010; Maes et al. 2012) along with calls to incorporate ES approaches into policy decisions and design (Hancock 2010; Ruckelshaus et al. 2015). Policy makers are also responding; for example Swedish national policy now states "By 2018, the importance of biodiversity and the value of ecosystem services are to be generally known and integrated into economic positions, political considerations and other decisions in society where it is relevant and reasonable to do so" (Swedish Government 2014). Recently the US government published a memorandum directing all Federal agencies to incorporate the value of natural, or “green,” infrastructure and ecosystem services into Federal planning and decision making. The memorandum directs agencies to develop and institutionalize policies that promote consideration of ecosystem services, where appropriate and practicable, in planning, investment, and regulatory contexts." (Whitehouse 2015).

Existing literature primarily proposes ideas for improving the use of ES in decision-making (Fisher et al. 2009; De Groot et al. 2010; Bateman et al. 2013; Jordan and Russel 2014) and has only just begun to consider how these approaches influence the decision-making process (Ruckelshaus et al. 2015; Spangenberg et al. 2015; Posner et al. 2016). It does not provide a precise description for assessment of ES approaches in environmental policy and decision-making processes, nor does it assess whether these applications make a difference in terms of changing decisions and improving outcomes. To address these gaps we first develop a framework for assessing more systematically the extent to which ES approaches are being integrated into environmental decision-making and second set forth some ideas for addressing the hypothesis that ES approaches make a difference.

In principle ES approaches might be applied to policies and decision-making instruments that address very different scales (e.g. ranging from the protection of biodiversity at a global level to local permits to hunt or to fell trees) and different parts of a decision-making process (e.g. environmental risk assessment as the basis for decision making). They could include awareness raising, regulation (command and control), permits (conditional), mitigation, compensation, subsidies (incentives), markets, strategies (EU), executive orders (USA), guidance documents, and communications. The decision-making process may be aided by methods and instruments like retrospective and prospective impact/risk assessments, scenario analysis, stakeholder meetings, benefit-cost/risk analysis, cost-effectiveness analysis, life cycle assessments, and checklists (Zhang et al. 2010; Bateman et al. 2011; Johnston and Russell 2011; Maltby 2013; Munns et al. 2015).

We first describe criteria that can be used to identify whether and to what extent ES approaches are being applied across a broad range of policy and decision-making instruments. ES approaches link ecosystem components (i.e. biophysical structures, ecological processes) to human well-being (Daily et al. 1997; Haines-Young and Potchin 2010) and central is the assumption that ES have clearly identified human beneficiaries (i.e. stakeholders) (Fisher et al. 2009). We therefore propose three criteria for identifying the application of ES approaches, one that deals with the ecological dimension of ES approaches, one that considers well-being of stakeholders, and one that connects the ecological dimension with the stakeholders. These are intended as a minimum set of necessary criteria on which a broad community of ES researchers and practitioners could agree, although it is recognized that additional criteria exist and may or need to be used. The criteria we propose are essential characteristics of ES across different applications. Other characteristics like those that relate to the scale of an assessment or the inclusion of stakeholder engagement are not unique to ES nor consistent across the use of ES methods. While it is critical to have an understanding of how people use and appreciate ecosystem goods and services, direct stakeholder engagement is not necessarily required for all decision-making instruments involving ES methods. Many methods estimate or assume importance to people based on how many people are likely using the service or by transferring data on values from other places (e.g. Rosenberger and Loomis 2000; Plummer 2009).

Our approach differs from other assessments of ES approaches, such as that of Matzdorff and Meyer (2014), by offering the minimum set of criteria rather than the ideal set for determining whether and to what extent ES approaches being used across a broad range of policy and decision-making instruments. Our approach complements the work of Schleyer et al. (2015), describing a method to move beyond counting and categorizing mentions of ES in policy, to assessing the degree to which ES is being applied and implemented.

To illustrate how the criteria can be used we apply them to a number of decision-making instruments. Finally we suggest how the criteria could be used to provide a rigorous assessment of the extent to which ES approaches have been applied, whether the expected benefits and challenges are realized, and where applied, and of whether ES approaches have made a difference.

All expert judgement including the selection of the cases in this paper arose out of the expertise present and discussions held at a Workshop jointly organized by the Society of Environmental Toxicology and Chemistry (SETAC) and the Ecological Society of America (ESA) in October 2014 (Maltby et al. This Issue).

CRITERIA FOR ASSESSING WHEN ES APPROACHES ARE BEING USED

Here we define three criteria that together set out the minimum necessary conditions for the use of ES approaches in policy and decision-making instruments. We consider an ES approach as ‘applied’ when all three criteria are met for a certain policy decision or decision framework. We refined this assessment by differentiating between low and high levels of meeting each criterion and thus level of application. A third option is that a criterion is not met.

As we discuss and demonstrate with examples below, these criteria can be used retrospectively to assess and compare existing policy decisions and frameworks. More broadly, they could be used to examine past patterns and trends in environmental policy decisions to determine whether ES approaches are being increasingly applied. They could also eventually be used to examine whether and how ES approaches have affected decision processes and outcomes. In addition, the criteria could be useful for planners and policymakers in developing new instruments or revising existing ones for environmental decision-making by highlighting key characteristics of ES approaches.

Criterion 1: Connects impacts all the way from ecosystem changes to changes in human well-being

- Definition: The decision (or assessment informing the decision) considers how the action will ultimately affect human wellbeing, through its impacts on the ecosystem.
- Levels of meeting the criterion: "High" means there is an explicit connection between the impact of action on ecosystem structures and processes and all other dimensions that cascade from it, includingbenefits (goods and services) to human wellbeing; "low" means there is only an implicit connection.

The core purpose of ES approaches is to link ecological impacts with human well-being (Haines-Young and Potschin 2010). When applied to environmental decision-making, this entails integrating natural and social sciences in a way that informs an understanding of how an action will affect human uses of and benefits from ecosystems. A conceptual representation of this connection for a decision links changes in stressors or inputs to an affected ecosystem (Figure 1). These changes alter ecosystem structures or processes in a way that affects the benefits humans receive from natural systems. To define a linkage from these changes to human well-being it is particularly important to identify affected final ES (Boyd and Banzhaf 2007), which are those most directly used or appreciated by humans. These final ES can contribute to human well-being in various ways, including through nature-based or ecosystem-dependent activities (e.g., economic production processes) or through human perceptions that give rise to "non-use" values.

For this criterion, an explicit connection is one that specifically defines at least one pathway from the decision's impacts on ecological processes, through final ES, and then to human well-being. This explicit connection might for example be expressed in a conceptual model, i.e. as a stand alone diagram or as the basis for a predictive modeling framework using ES indicators for each step (Mononen et al. 2016), that adds specificity to the framework (Figure 1). An implicit connection, on the other hand, is one that acknowledges the links to human well-being but without specifying the links through a detailed conceptual model.

Criterion 2: Considers all relevant ES affected by the decision

- Definition: The decision (or assessment informing the decision) considers all relevant ES, where relevance means that the services are important for the stakeholders and expected to be significantly changed, either directly or indirectly, by the decision/action.
- Levels of meeting the criterion: "High" means the decision process makes full use of existing natural and social science evidence to define as many relevant pathways as possible linking ecological and human impacts (at appropriate spatial and temporal scales). "Low" means identification of relevant ES is based only on the most obvious direct links, not addressing the complex ecological connectivity among ecosystem components and services.

This criterion highlights the comprehensiveness of the decision analysis in identifying as many potentially relevant ES pathways as possible. A "relevant" ES or ecological production process is one that could be impacted by the action directly or indirectly and could make a significant contribution to human well-being, where significance will depend upon context and needs to be considered on a case by case basis (Iniesta-Arandia et al. 2014). The identification of relevant pathways may be informed by existing classification systems for ES (Landers and Nahlik 2013;

Haines-Young and Potschin 2013; USEPA, 2015) and, as with the first criterion, conceptual diagrams may be used to illustrate these linkages and specify which services are taken into account through ecological and economic production processes (Olander et al 2015; Bruins et al. This issue). The process of building such conceptual diagrams with experts and stakeholders can also be an effective way to identify relevant ES pathways of interest to affected communities.

Criterion 3: Considers and compares the changes in well-being of different stakeholders

- Definition: The decision (or assessment informing the decision) considers and compares the changes in well-being of different stakeholders, including those who are influenced by changes in ES flows.
- Levels of meeting the criterion: "High" means stakeholders have been identified in a transparent way at all relevant spatial and temporal scales and their preferences/values have been elicited or estimated in a detailed way along the process of decision making; "low" means stakeholders have been involved in a limited part of the process, or limited in relevance, and their preferences and values are only expressed in generic terms.

This criterion emphasizes that full application of an ES approach requires consideration of how different beneficiaries or stakeholders are affected by a decision. This consideration can include balancing the relative gains and losses among and within different groups as a result of changes in ES. To fully evaluate and compare these relative changes in well-being will typically require characterization of preferences, either in monetary or non-monetary terms. Alternatively, qualitative indicators may be used to provide more rough measures of the relative direction and general magnitude of changes in well-being.

We consider this set of 3 criteria to be the simplest and most distinctive for ES approaches, based on the rationale that ES approaches need to consider at minimum the link between ecosystems, ecosystem services and human well-being.

HOW THE CRITERIA APPLY

In the previous section we have described a minimum set of criteria for ES approaches in decision-making. The criteria can be used to answer the question of how far ES approaches are being used in a policy decision or decision frameworks. Here we show the application of the criteria to a number of different instruments that vary in scope, spatial and temporal scale and jurisdiction. We have selected a limited set of diverse cases to demonstrate the generality of our approach, drawn from the practices of the authors. We chose to differentiate in scale from regional to local, in regulating bodies, and in type of environmental issues. The examples comprise national instruments under the US Clean Water Act, instruments related to the European regulation for marketing and use of plant protection products, and municipal instruments for green urban planning. We have developed an analysis format that facilitates the systematic application of our criteria to assess a range of policy and decision support instruments. The format describes the type of policy, the relevant scale(s), the key decisions or questions, the decision-maker, and the underlying documents, and includes a judgement of how far the ES criteria have been implemented in the decision-making. Three categories are used for scoring the level by which the criteria are met: high, low, and not. Complete tabulations for the examples treated below are given in Table 1. Our examinations of these decision instruments provides examples of how the criteria can be applied in future studies, and the outcome of such studies can help to assess the level of permeation of ES approaches in policy decisions and frameworks or when policy and instruments are being developed or revised.

Decisions under the USA Clean Water Act

Originally enacted in 1972, the Clean Water Act (CWA) is the federal law governing water pollution policy in the United States. Although the concept of ES had not been articulated at the time of its passage, the Act's focus on supporting human uses (and thus benefits) is broadly consistent with an ES perspective. In particular, it defines the goal of achieving a "fishable/swimmable" level of water quality wherever attainable, and it requires states to consider other human uses and benefits, such as public water supply, agricultural, industrial, and navigational uses. The US Environmental Protection Agency (USEPA) has primary responsibility for implementing CWA policies. In this role, the USEPA has been charged with decision-making authority, often in coordination with individual states. These decisions offer a number of useful examples for examining whether and to what extent an ES approach has been applied in implementing the Act. Below, we discuss three examples for the CWA. The results are summarized in Table 1.

First, at a national level, one of the main regulatory programs under the CWA is the effluent limitations guidelines (ELG) program which regulates pollutant loads from point source categories. In setting these guidelines for existing facilities, the key decision for USEPA is selecting numeric pollutant limitations. In determining limits based on "best practicable technology" the CWA requires USEPA to consider the total cost of treatment technologies in relation to the effluent reduction benefits achieved. To support decision-making for the recently promulgated ELGs for construction sites, USEPA conducted an environmental impacts and benefits assessment (USEPA 2009) that meets all of the criteria of an ES approach at a "high" level. In particular, the analysis estimates how projected reductions in sediment loadings would improve water quality indicators, and these indicators were directly linked to values (criterion 1, high) for a range of ES (criterion 2, high). The analysis also includes and compares benefits to multiple stakeholders (criterion 3, high), including those associated with households' willingness to pay for improved instream conditions and avoided costs to drinking water treatment plants, reservoir owners, and navigational users.

Second, at a state-level, USEPA also plays a role in setting water quality criteria to achieve fishable/swimmable and related goals. For example, in 2010 USEPA established water quality standards for nutrients in lakes and flowing waters in Florida (USEPA, 2010a). The key decision in this case was establishing numeric instream concentration limits for nitrogen, phosphorus, and chlorophyll a. To reach this decision, USEPA conducted an economic analysis, which also meets all of the criteria of ES approaches. In this case, the analysis translated reduced nutrient concentrations into a general water quality index which was then linked to households' values for improved water quality (criterion 1, high). The analysis also identified other relevant ES pathways affected by improved water quality, such as reduced drinking water treatment costs (criterion 2, high). Although households' benefits were quantified, the benefits for the other ES and beneficiaries were not (criterion 3, low). In this sense, the analysis was somewhat less comprehensive than the previously described ELG analysis; however, it did qualitatively assess and compare how different groups would be affected.

Third, at a more local level, USEPA and the states' policy choices include use attainability decisions. In these cases, decision-makers must determine whether specific water bodies can be exempt from the requirement of achieving the fishable/swimmable goal. For example, the state of New York conducted a use attainment analysis in the 1990s for Cayadutta Creek to determine if it could continue to be exempt from supporting fish propagation (NYSDEC 1997). As discussed in USEPA (2010b), these decisions can include consideration of whether the costs of achieving the goal are exceeded by the ES benefits that would be provided. In practice, however, existing use attainability analyses have generally not included assessments that meet any of the criteria of ES approaches (criteria 1, 2 and 3 are not met).

Instruments for decision-making regarding pesticides

The placing of plant protection products on the market in the European Union is regulated by Regulation (EC) 1107/2009 (EU 2009). EU Regulations have binding legal force throughout member states as soon as they are passed. Guidance documents for the environmental risk assessment of pesticides (SANCO 2002a, b) were originally developed in response to Directive 91/414/EEC. They are currently being revised under the auspices of the European Food Safety Authority (EFSA) to meet the subordinate data requirements Regulation of the Regulation (EC) 1107/2009. We discuss here two examples of instruments for pesticide risk assessment, one supranational on the development of specific protection goals in pesticide risk assessment, and a local-regional tool for decision-making on actual pesticide use. The results are summarized in Table 1.

Regulation (EC) 1107/2009 requires a high level of protection (e.g. no unacceptable effects on the environment); however, the protection goals given in the regulation are too general for effective ecological testing and thus risk assessment. At the start of the guidance documents revision process, EFSA issued a scientific opinion on the development of specific protection goals for the environmental risk assessment of pesticides (EFSA 2010; Nienstedt et al. 2012). An ES approach was chosen to enable the translation of general protection goals in the Regulation into specific protection goals (SPGs) to be used in the future revision of guidance documents for risk assessment. For this the ecosystem services which could potentially be directly or indirectly (e.g. via trophic interactions) affected by normal agricultural use of pesticides and the groups of organisms which generally constitute the most important key drivers for those ecosystem services were identified. Subsequently, SPGs for each of the key drivers were identified. The SPGs are important for defining what to protect and where to protect it. They are defined both in terms of the magnitude and the scale (temporal and spatial) of impact. EFSA intends to use the SPG options as well as the general concept of ES as input for the dialogue between risk managers and risk assessors for the problem formulation phase during the next steps of the revision of the guidance documents (EFSA 2010, 2013).

The 2010 EFSA scientific opinion proposes SPGs to protect ecosystems against unacceptable effects of pesticides. While an explicit connection between pesticide impacts on ecosystems and human well-being was outside the scope of the opinion, this connection was implicit in the approach adopted to define SPGs (criterion 1, low). The opinion worked from the standard list of ecosystem services contained in the Millennium Ecosystem Assessment (MA 2005). The relevance of each service in key components of European agricultural landscapes was determined by expert judgement. Distinction was made between in-crop and off-crop situations (terrestrial edge of the field and more remote natural areas), as well as between small surface waters and large water bodies (including wetlands and marine environments) (criterion 2, high). The EFSA opinion itself did not consider nor compare the changes in well-being of different stakeholders (criterion 3 is not met).

In Europe, pesticides are allowed on to the market after passing the risk assessment procedures, and if necessary risk mitigation measures (restriction to certain uses) have been taken. However, individual farmers have to make many decisions about pesticide use within the regulatory context, where an ES approach could be used to inform their decision-making. Alix et al. (2014) provide a method for such local to regional decision-making, which explicitly connects impacts on ecosystems to human well-being and thereby meets criterion 1 for an ES approach, although limited data availability makes the scientific underpinning of the connections weak (criterion 1, low). Aggregate data are used as indicators for ES and a systematic review of possible relevant ES is missing (criterion 2, low).Identified stakeholders are farmers, and other 'values' are derived from public information. Given the nature of the decision (how to apply a pesticide in tomato fields) and the absence of a regulatory context for this decision (i.e. the pesticide has been approved) a more extended stakeholder consultation might not be necessary (criterion 3, low).

Municipal instruments for green urban planning

The Stockholm Royal Seaport is a city district under development profiled as a sustainable city district. It is situated close to open water and adjacent to the National city park. There are many instruments and projects associated with this development, and efforts are being made to explore, develop and showcase new sustainable solutions (www.stockholmroyalseaport.com). We discuss here the Environment Plan and the Green Area Factor instrument. The results are summarized in Table 1.

A foundational instrument to steer development in this city district is the General plan for the environment and sustainable city development in the Stockholm Royal Seaport (City of Stockholm

2010), which explains the requirements for sustainable urban development with a particular focus on climate change adaptation. This Environment Plan acknowledges on a general level human dependence upon ecosystem services but does not explicitly describe the links from ES to well-being (criterion 1, low). The plan refers to "valuable ecosystem services" and specifically mentions ES as important to create urban spaces where people want to live, to mitigate climate change and to support biodiversity (criterion 2, low). There is no systematic consideration of all relevant ES. Furthermore the plan states that collaboration and dialogue is necessary and that a successful process to achieve the visions of a sustainable city requires active participation from different city departments, builders, entrepreneurs and citizens (criterion 3, low).

One of the instruments mentioned in the Environment Plan, to bring the plan into practice, is the "Green Area Factor". The plan requires that "each property and public space must achieve at least the green area factor specified by the city." Green area factor is a policy instrument to guide inner city structures, on the scale of city blocks, towards desired levels of "green area". It relates to the percentage of eco-efficient area of the total plot area. Different forms of this instrument (similarly named, e.g. green area ratio and green space factor) have been tailored for different cities. These are all derivatives from the Biotop Area Factor developed for urban planning in Berlin (Berlin Senate Department for Urban Development and the Environment 2014). In development of the Stockholm Royal Seaport builders are required to achieve a minimum threshold of "green area." They are tasked to decide how to meet the city's requirements by choosing a sufficient number, or area of, "green elements" from a list of weighted choices provided by the municipality (City of Stockholm 2011). Green elements mentioned in the guidance document are for example oak trees, butterfly restaurants and visible green roofs. The concept of ES is referred to in the guidance for designing the plot and introducing "green elements" is predominately motivated with reference to enhanced well-being. This instrument thus expresses a connection from ecosystems change to human well-being (criterion 1, low). The builders do not have to consider all relevant ES, nor decide what constitutes relevant ES within the project, but they are required to pick green elements from three categories to achieve a desired “balance between different wanted functions” (criterion 2, low). These categories target biodiversity, recreation and climate adaptation respectively. Stakeholder preferences are not captured with this instrument nor are effects on wellbeing from implementing “green elements” captured or quantified (criterion 3 is not met).

Conclusion application of the criteria

These case studies show that the criteria can be applied to many different decision-making instruments, ranging from the supranational to the local scale. The criteria can distinguish between policies and implementation of policies that do incorporate ES and those that do not. The criteria can be applied regardless whether particular ecosystem services terminology is being used. The application of the criteria can give insight into level of assimilation of ES approaches in for instance national legislation, if a systematic assessment is made of the relevant environmental instruments. Additionally, applying the criteria may help to identify areas for improvement.

CONCLUSIONS

Much has been written and claimed regarding the use and benefits of the implementation of ES approaches in policies and decision making. Much effort is going into research on how to translate the ES concept into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making. However the specific requirements for implementation and actual realized benefit of such approaches have not been systematically or rigorously evaluated. We have sought to develop a transparent framework that helps to define and identify ES approaches and sets the stage for evaluating whether these approaches provide a policy advantage for environmental protection. This framework evaluates the degree to which specific policies/programs meet a minimum number of criteria that many working within the area would find acceptable as characterizing ES approaches. These criteria include: 1) making explicit connections between changes in ecosystems and their impact on human well-being;

2) considering all the relevant services affected by a decision; and 3) considering the implications of the differential changes in ecosystem services for different stakeholders. Through a variety of case studies we have then demonstrated the general usefulness of these criteria in characterizing ES approaches.

Looking forward, the criteria that we have developed above could be used to assess the extent of the use of ES approaches in policy implementation. The three criteria described above could be used to develop a scoring system for a systematic review of existing policy instruments and their implementation documents (regulations, guidance documents, directives, regulatory studies, risk assessments, etc.). Hall and O'Toole (2000) and Egoh et al. (2007) provide examples of careful selection of the policy instrument sample to be used and of systematic coding and scoring procedures. Such a systematic review could consider if, and to what extent, ES approaches have been used in different types of policy instruments (e.g., regulatory requirements, incentive programs, etc.), applied in different contexts and parts of decision-making (e.g., water pollution, chemical risk assessment, forest management, etc.), implemented at different scales (e.g., regional, national, state, local), and in different jurisdictions (US, EU). It might also assess in what way they are applied in the decision process: conceptual, strategic or instrumental (McKenzie et al. 2014). The scoring system could also assess to what extent ES approaches have been incorporated based on the number of criteria fulfilled.

A systematic assessment of policy instruments could also help to identify where ES approaches have yet to be incorporated – types of policies, contexts, and scales. It provides an opportunity to consider and assess what the barriers to incorporation might be: for example scientific, legal or regulatory requirements, political expediency, concerns about cost effectiveness or practicality. An analysis of these barriers would require appropriate social science expertise to understand the legal or economic constraints. For example, legal analysis of two important U.S. laws, the National Environmental Policy Act and Federal Lands Policy and Management Act, explore if legal barriers exist that would limit the use of ES approaches in their implementation (Bear 2014; Smyth 2014).

Moving forward it is essential to assess the validity of the presumed benefits of ES approaches. Once we can objectively identify policies and programs that added or increased the use of ES, through criteria like ours, it will be possible to begin to assess whether this has resulted in the expected improvements. There are 3 aspects to this assessment: (1) Does it improve the decision process? (2) Does it change the decision? (3) Does it improve the outcome? Assessing if ES approaches improve decision-making processes might involve surveying decision-makers or developing qualitative analyses of case studies to consider if the decision process was improved and how (MacDonald et al 2014; Primmer et al. 2015). Assessing if ES approaches change decisions and how they change them, might involve a comparison of similar decisions with and without ES information. Or they might involve taking existing decision processes, providing decision-makers with a comparison of outcomes with and without ES, and examining whether decision-makers see things differently as a result. The question whether the use of ES approaches in decision-making changes the social and ecological outcomes of a type of decision (e.g. management of national forests, chemical risk assessment) can be answered by using methods such as impact assessment or program evaluation (Ferraro and Pattanayak 2006; Ferraro 2009). Such an approach can be used where ES approaches lead to specific types of policy choices (e.g. use of green infrastructure or payments for ES). This research could take advantage of cases where use of ES in decisions and policy choices differ across states or countries, or experiments designed where such policies are used in some places but not others. For example, Andam et al. (2008) have applied this method to assessing the effectiveness of a protected area network in Costa Rica in reducing deforestation and Joppa and Pfaff (2010) have used them to look more broadly at how protected areas are working globally.

We therefore consider that the proposed set of criteria can be useful in answering a wide variety of questions about the future application and development of ES approaches and draw attention to where the greatest challenges are, helping to target integration of ES approaches into policy where it can be most effective.

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Legend to figure 1.

Figure 1. Depiction of criterion 1, showing the connection between ecosystems and human well-being (socio-economic systems). Intermediate services capture the cascade of ecological changes that lead to a change in a final service directly valued by people. Some ecological changes can be an intermediate service in one situation and a final service in another. Human activities that use these services can include enjoying or appreciating nature (e.g. using trail networks, fishing guides etc.) as well as provisioning activities (agriculture, fishing).

Legend to table 1.

Table 1. Tabular assessment of application of a minimum set of criteria to assess the application of ES approaches in environmental policy and decision-making. Strength of application of the criteria is classified in three categories: yes (high), yes (low), no.

Table 1.

Policy	Type of policy	Scale	Key Decisions/Questions	Decision Maker	Analysis Document(s)	ES Approach Criteria		
						1. Connects impacts all the way from ecosystem changes to changes in human well-being	2. Considers all relevant ES affected by the decision	3. Considers and compares changes in well-being of different stakeholders
Effluent Limitations Guidelines (ELGs) for discharges associated with construction and development activities	Pollution control regulation	National	For construction sites 1. What turbidity limits in discharges? 2. What management practices to require?	USEPA Office of Water	USEPA (2009)	Yes (High): Links changes in discharges to changes in water quality condition to changes in human well-being	Yes (High): Includes ES related to navigation, water storage, drinking water treatment, water-based recreation, and non-use, but analysis is based mainly on existing data and models (i.e., did not involve new stakeholder engagement)	Yes (High): Estimates and compares values for navigation sector, reservoir operators, drinking water utilities, and households
Water Quality Standards for Nutrients for Lakes and Flowing Waters in Florida	Water quality standards	State-level	What level to set for instream nutrient-based concentration limits?	USEPA Office of Water	USEPA (2010)	Yes (High): Links changes in discharges to changes in water quality condition to changes in human well-being	Yes (High): Includes and discusses ES related to drinking water treatment, human health, aesthetics, water-based recreation, and non-use, but analysis is based mainly on existing data and models (i.e., did not involve new stakeholder engagement)	Yes (Low); Only quantifies benefits for households; other benefits are described in more qualitative terms

Policy	Type of policy	Scale	Key Decisions/Questions	Decision Maker	Analysis Document(s)	ES Approach Criteria		
						1. Connects impacts all the way from ecosystem changes to changes in human well-being	2. Considers all relevant ES affected by the decision	3. Considers and compares changes in well-being of different stakeholders
Cayadutta Creek Use Attainability Analysis	Designated use standard	Local	Allow designated use assignment that does not support fish propagation?	New York State Department of Environmental Conservation (NYSDEC)	NYSDEC (1997)	No	No	No
Deriving specific protection goal options for pesticide risk assessment	Scientific opinion as basis for guidance documents	EU	Selection of specific environmental protection goals in guidance documents	EU Risk managers	EFSA 2010	Yes (Low): Connection between pesticide impacts and human wellbeing was outside remit, but was implicit in the approach. Refrained from identifying all ecological service providing units and did not distinguish between intermediate and final ecosystem services.	Yes (High): Used a standard list of ecosystem services The relevance of each service was determined systematically by expert judgement.	No
Site-specific study for identified good agricultural practices at local level	Voluntary action by industry	Local (farm)	Selection of good agricultural practices in a concrete crop and location	Farmers	Alix 2014	Yes (Low): Explicitly connects impacts on ecosystems to human wellbeing, but limited data availability makes the scientific underpinning of the connections weak.	Yes (Low): Aggregate data are used as indicators for ecosystem services and a systematic review of possible relevant ecosystem services is missing.	Yes (Low): Identified stakeholders are farmers, and other ‘values’ are derived from public information. An extended stakeholder consultation might not be necessary given the decision and absence of a regulatory context.

Policy	Type of policy	Scale	Key Decisions/Questions	Decision Maker	Analysis Document(s)	ES Approach Criteria		
						1. Connects impacts all the way from ecosystem changes to changes in human well-being	2. Considers all relevant ES affected by the decision	3. Considers and compares changes in well-being of different stakeholders
General plan for the environment and sustainable city development in the Stockholm Royal Seaport.	Urban planning	City district	What are our requirements for sustainable urban development?	Municipality, City of Stockholm.	City of Stockholm. 2010	Yes (Low): Links, mostly implicit, changes in urban green space to wellbeing.	Yes (Low): Considers "valuable ES" at the general levels and specifically mentions ES in relation to the goals of creating an spaces where people want to live, to mitigate climate change effects and to support biodiversity. There is no systematic consideration of all relevant ES.	Yes (Low): Stakeholders are implicitly represented by the City council. Stakeholder consultations are required in the program, though it is not specified how stakeholders are identified.
Green Area Factor for the Stockholm Royal Seaport, version 2.0.	Urban planning	Building plot or city block for urban development	How to meet the city's requirements of reaching a Green Area Factor of 0,6 by choosing and implementing a sufficient number of, or area of, "green elements"?	Builder of the plot	City of Stockholm. 2011	Yes (Low): The arguments presented for choosing and implementing "green elements" is predominately to enhance wellbeing. Increase in wellbeing is explicitly expressed but not quantified.	Yes (Low): Considers a comprehensive set of pathways to ES delivery. Restricted to the spatial scale of the city block. Decisions rest on a predefined list of "green elements".	No: Exploring and comparing stakeholder preferences is not required. Increase in wellbeing is assumed, and an important rational, when implementing "green elements"

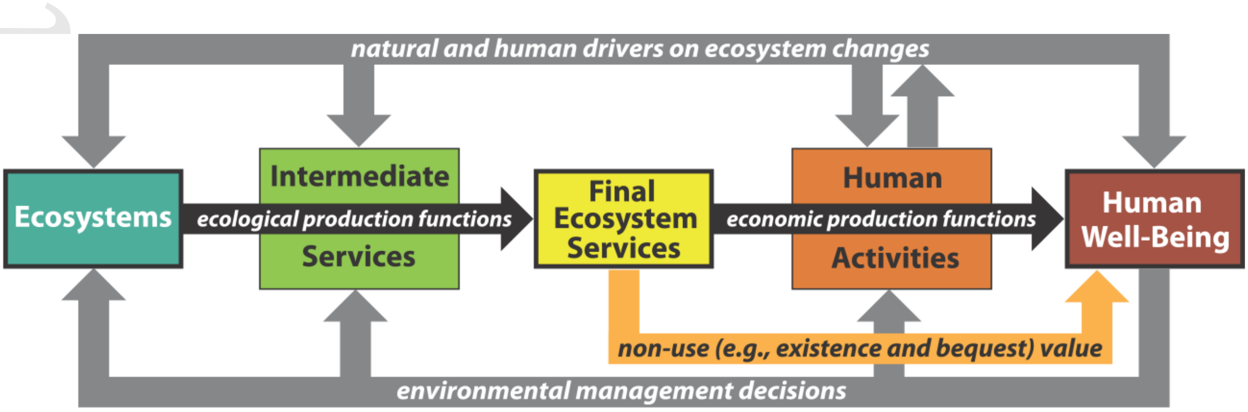
natural and human drivers on ecosystem changes
Ecosystems
Intermediate
ecological production functions
Services
Final
Ecosystem
Services
Human
economic production functions
Activities
Human
Well-Being
non-use (e.g., existence and bequest) value
environmental management decisions

Figure 1