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Getting the measure of ecosystem services: a social–ecological approach

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Getting the measure of ecosystem services: a social–ecological approach

Belinda Reyers[1,2*], Reinette Biggs[2,3], Graeme S Cumming[4], Thomas Elmqvist[5], Adam P Hejnowicz[6], and Stephen Polasky[7]

Despite growing interest and investment in ecosystem services across global science and policy arenas, it remains unclear how ecosystem services – and particularly changes in those services – should be measured. The social and ecological factors, and their interactions, that create and alter ecosystem services are inherently complex. Measuring and managing ecosystem services requires a sophisticated systems-based approach that accounts for how these services are generated by interconnected social–ecological systems (SES), how different services interact with each other, and how changes in the total bundle of services influence human well-being (HWB). Furthermore, there is a need to understand how changes in HWB feedback and affect the generation of ecosystem services. Here, we outline an SES-based approach for measuring ecosystem services and explore its value for setting policy targets, developing indicators, and establishing monitoring and assessment programs.

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Galileo once wrote, "Count what is countable, measure what is measurable, and what is not measurable, make measurable", a dictum that has set the course for empirical science across the disciplines. This axiom has recently become central to sustainability science and policy, where greater recognition of the world's environmental and development challenges has fostered efforts to make complex concepts such as biodiversity and poverty "measurable", to set policy targets and measure progress in reaching those targets (eg targets associated with the Convention on Biological Diversity [CBD] and the United Nations Millennium Development Goals).

In a nutshell:

- When measuring ecosystem services, it is important to account for the social and ecological factors, and their interactions, involved in service production
- Ecosystem service measurement should capture the consequences of changes in social and ecological factors for multiple services, their benefit flows to different beneficiaries, and corresponding feedbacks
- If ecosystem services are measured through the use of a social–ecological systems-based approach, it is possible to develop improved policy targets and indicators capable of accounting for the dynamic and complex nature of ecosystem services

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Although there have been advances toward making these multidimensional policy targets measurable, much work remains to be done (eg Attaran 2005; McArthur *et al.* 2005; Walpole *et al.* 2009). In principle, there are two major obstacles impeding further progress: (1) inadequate data with which to measure changes in biodiversity, poverty, and other components relevant to policy targets (Scholes *et al.* 2008), and (2) the general immeasurability of the policy target of interest, often on account of poorly understood, unquantified, and complex concepts (eg biodiversity, poverty, and well-being). In the rush to address data inadequacy issues, the latter has been largely overlooked, resulting in a plethora of measures and indicators (based on existing data) that frequently fall short of their intended purpose (Mace and Baillie 2007).

As ecosystem services increasingly take center stage in the global conservation and development arenas, a proliferation of measures (Egoh *et al.* 2007), values (Liu *et al.* 2010), and indicators (Layke *et al.* 2012) has emerged (Panel 1). However, scant attention has been paid to what it is we should be measuring. Ecosystem services represent a complex and diverse concept, with broad and often conflicting definitions (see Nahlik *et al.* [2012] for a review); this has inhibited the development of concise operational definitions and measures (Reyers *et al.* 2012), as well as coherent and comprehensive policy objectives and targets (Perrings *et al.* 2010, 2011).

In response, several frameworks aimed at advancing the operational understanding of ecosystem services have been developed (eg Fisher and Turner 2008; de Groot *et al.* 2010; Haines-Young and Potschin 2010; Rounsevell *et*

Panel 1. Selected definitions

Several related terms are used in the establishment and monitoring of policy targets. The term *measure* (or measurement) is used to refer to the actual assignment of a number to a state, quantity, or process derived from observations or monitoring. For example, bird counts are a measure derived from an observation. An *indicator* is defined as a measure (or index made up of several measures) that conveys information about more than itself and serves as an indication of a feature of interest. For instance, bird counts compared over time exhibit a trend that can be used as an indicator of the success of conservation actions for birds. Similarly, counts across different vertebrate groups worldwide can be combined into a composite *index* to form an indicator of the success of conservation actions for species. The Living Planet Index is an example of such a broad indicator. Indicators are typically used for a specific purpose (eg to provide a policy maker with information about progress toward a target). *Targets* refer broadly to goals or objectives. The CBD has several targets in its new strategy, including Target 14, which states that: "By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable".

al. 2010; Mace *et al.* 2011). These frameworks have helped to clarify ecosystem service definitions and classifications, especially in the context of the economic valuation of single services. However, the complex, interconnected, dynamic nature of ecosystem services has so far prevented researchers from measuring them in a way that clarifies the consequences of ecosystem service change for human well-being (HWB), which has impeded informing the complex trade-offs associated with sustainability-related policy and management decisions.

We believe that what is required is an evolution of these frameworks and the current simplistic measures of ecosystem services, which dominate policy formulation, toward a framework and a set of measures that make explicit the dynamic linkages between the social and ecological structures and processes (hereafter "factors") associated with ecosystem services, HWB, and their interactions (WebPanel 1). Although such an integrated framework has yet to be developed, we suggest that advances in our understanding of coupled social–ecological systems (SES; Berkes *et al.* 2003) will promote its creation. An SES-based approach adopts a more integrated view of the social and ecological factors related to ecosystem services and HWB, including non-linear feedbacks, trade-offs, and interactions associated with service provision. Here, we explore how a better understanding of SES can help to improve current and develop new measurements of ecosystem services, as well as contributing to more explicit policy targets.

An SES approach for ecosystem services measurement and management

An SES approach to ecosystem services measurement (Figure 1) highlights the importance of measuring: (1) the social and ecological factors that produce ecosystem services, (2) the bundles of services produced and their benefit flows, (3) the changes in HWB and their influence on SES management, and (4) the changes in SES management and their effect on (1). Below, we explore each of these stages.

Social–ecological production of ecosystem services

Current practice in ecosystem service-related studies focuses on the concept of ecological production functions, which combine a set of biophysical variables (eg soil type, tree cover) to model the production of an ecosystem service. This practice emphasizes the ecological factors associated with ecosystem service production, and often excludes the social factors also involved. The studies that include social factors tend to do so after service production, as measures of use or value (eg Nahlik *et al.* 2012). An SES approach broadens the concept of ecological production functions by recognizing that in the human-dominated environment, social factors such as skills, management regimes, and technology are also involved in ecosystem services production (Walker and Salt 2006; Easdale and Aguiar 2012) – a fact that, while broadly understood, is currently not apparent in ecosystem services frameworks. For example, to model the production of cereal crops, one needs to incorporate biophysical conditions of soil and rainfall, as well as the application of technologies like irrigation and fertilizer, plus the skills of the farmer. Even beyond technologically enhanced provisioning services, there are few services that do not involve social factors in their production (eg built infrastructure for water services, societal capacity to manage and govern communal resource productivity, or beneficial species management and enhancement; Figure 2). Cultural services have particularly strong social factors involved in their production (eg recreational infrastructure and preferences, sacred site traditions and management) and have for the most part not been successfully modeled using ecological production functions (Daniel *et al.* 2012).

Land use – which reflects the interactions between the biophysical characteristics of the land and the human management thereof – provides a relatively uncomplicated starting point for exploring these social–ecological production functions and is already included in several production functions currently in use (eg flood regulation and sediment retention; Kareiva *et al.* 2011). However, for many ecosystem services, more work is required to identify the social factors, and their interactions with ecological factors, needed to develop social–ecological production functions that can satisfactorily model the production of these services.

Bundles of services and benefit flows

As with many existing ecosystem services frameworks, an SES approach highlights the importance of moving

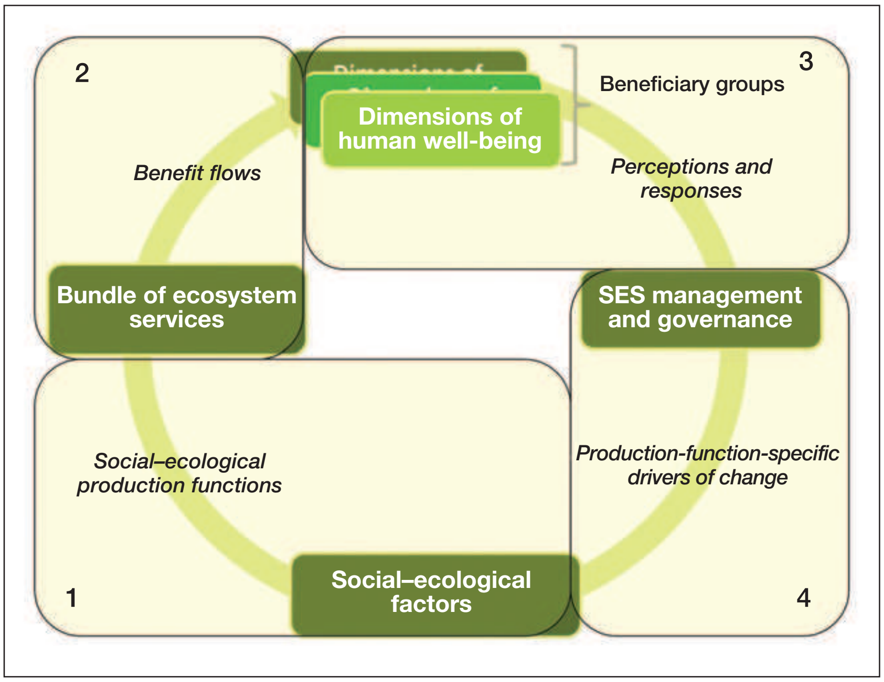

Figure 1. *An SES approach to identifying social–ecological factors and interactions is needed to measure and manage ecosystem services and HWB. Such an approach highlights the importance of measuring: (1) the social–ecological factors involved in the production of ecosystem services, (2) the benefits that flow from bundles of interacting ecosystem services, (3) the impacts of these benefit flows on specific dimensions of HWB across beneficiary groups and the impact of these changes on SES management and governance, and (4) the influence of management and governance on the SES factors that underpin ecosystem services.*

beyond measuring the supply of services provided by an area (eg crop production, water regulation) to metrics that provide an indication of the actual benefits gained by people (eg drinking water, food, flood protection). These include economic, social, and cultural benefits, which are often referred to as goods or final services in other frameworks (see Nahlik *et al.* 2012). Measuring benefits requires an in-depth understanding of SES to identify how the benefits from ecosystem services are distributed to, or accessed by, different groups of beneficiaries (Cowling *et al.* 2008). Despite their importance in ecosystem service definitions and frameworks, ecosystem service benefits, as well as their flow to beneficiaries, remain a poorly understood and quantified component of measurement and monitoring programs (Carpenter *et al.* 2009).

In contrast to existing frameworks, an SES approach aims to identify the benefits associated with a bundle of interacting services and to see how those benefits flow to different beneficiary groups (Daw *et al.* 2011; Syrbe and Walz 2012). Few existing frameworks focus on evaluating the consequences of a particular intervention on the total bundle of ecosystem services, although services interact with one another and decisions to enhance a particular service will affect the type, mix, and magnitude of other services provided by an SES (Bennett *et al.* 2009). An SES approach emphasizes that (1) understanding changes in the total bundle is the only way to assess the consequences of changes in SES for HWB and whether and how greatly changes in ecosystem services matter to people, and (2) a meaningful assessment of trade-offs between services requires an evaluation of the net benefit flow changes and their consequences for HWB, rather than simply an assessment of the changes in specific services.

Human well-being – consequences and responses

Many ecosystem service programs only measure the benefits provided by services. However, understanding the impacts of these benefits on HWB across different groups of beneficiaries is central to most policy and management choices. Like ecosystem services, HWB is a complex and multivariate concept, dependent not only on ecosystem services but also on a multitude of other ecological and social factors and their interactions. While many frameworks make the link to HWB, few have advanced our ability to measure HWB and untangle its links to ecosystem services, making current practices reliant on economic valuation or broad qualitative statements about well-being. An SES approach clarifies the need to: (1) stipulate the beneficiary groups being considered, (2) identify and measure the relevant dimensions of HWB (eg security, health), and (3) link changes in different HWB dimensions to the benefit flows from the ecosystem services bundle (Daw *et al.* 2011; Rogers *et al.* 2012).

The SES approach also highlights the need to move beyond changes in HWB to explore how these changes feed back to influence governance and policy and, consequently, SES and their services. Existing frameworks require simply monitoring the indirect drivers of change (eg sociopolitical and economic; MA 2003; TEEB 2010) or indicators of governance and management (eg protected area extent, restoration programs implemented) without an understanding of what drives these changes and what constituents of well-being are most important in motivating changes in governance and policy. A better understanding of how to achieve these changes to encourage more sustainable management of SES has been identified as a key gap in transitioning to more sustainable development trajectories (Folke and Rockström 2011; Westley *et al.* 2011). This gap in understanding will hamper progress in the learning processes that are fundamental to building resilience and addressing uncertainty in SES (Cundill *et al.* 2012). Recent frameworks for the

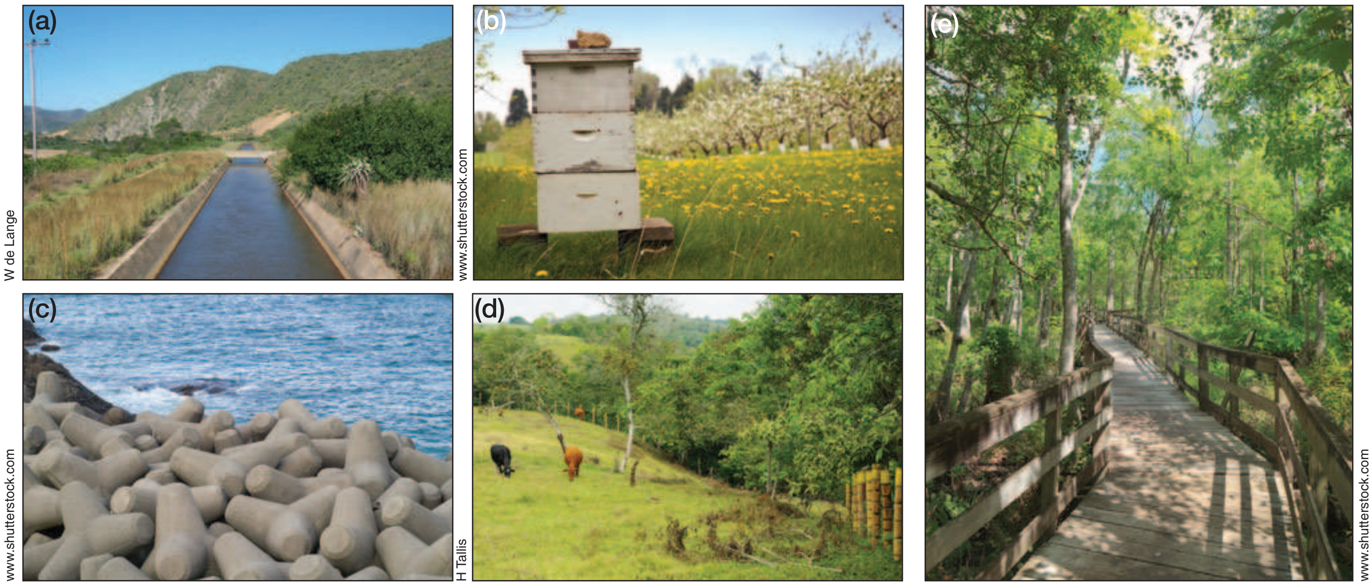

Figure 2. *Accurately modeling the production of most ecosystem services requires the inclusion of social–ecological production functions that take into account social factors underpinning ecosystem services; for example: (a) irrigation canals that deliver water for food production in dry regions, (b) beehive management for pollination and fruit production, (c) engineered infrastructure to enhance coastal protection services, (d) grazing management and fencing to protect riparian areas for water services, and (e) trail infrastructure and maintenance to enhance recreation services.*

study of SES (Berkes *et al.* 2003; Anderies *et al.* 2004; Ostrom *et al.* 2007; Chapin *et al.* 2009; Ostrom 2009) will be critical in shifting from simply tracking change to enabling change to be managed and directed.

Governing and managing social–ecological factors underpinning ecosystem services

An SES approach makes clear the need to link SES governance and management with SES changes that underpin ecosystem service generation, which is crucial in assessing the effectiveness of and suggesting ways to improve ecosystem service-related policy, decision making, and management (Folke *et al.* 2005; Carpenter *et al.* 2009). We follow Biggs *et al.* (2012) in differentiating between SES governance, which includes the social and political process of defining goals for SES management and resolving trade-offs, and SES management, which is defined as the actions taken to achieve these goals.

Many indicators of the link between SES governance and management, and the social and ecological factors underpinning ecosystem services, currently focus on drivers of change in SES (eg land-cover changes, pollutant levels). However, knowing the area of forest lost or the amount of pollutants in a river does not necessarily indicate how this translates into loss of ecosystem services or how to respond to this change. An SES approach argues that these measures of drivers must be (1) explicitly connected to changes in SES governance or management and (2) converted into measures of impacts on the social and ecological factors relevant in the production function of key ecosystem services. For example, an SES approach applied to the commonly used indicator of "increases in protected area coverage" proposes an explicit link to the policy that led to this increase as well as a link to the impacts of such an increase on the social or ecological factors (eg increases in populations of beneficial species) underpinning ecosystem services, in order to help in determining which forms of governance work in improving ecosystem services.

Application of SES learning: from intractable targets to efficient indicators

The set of policy targets proposed in the CBD's new strategic plan (www.cbd.int/sp/targets), together with existing national and international conservation and development policies, present a "minefield" of competing visions, missions, and goals for implementing agencies to select and measure progress. We suggest that the SES approach described above can be useful to these implementing agencies by providing a mechanism to (1) explore conservation and development policies and related monitoring programs; (2) identify possible gaps, conflicts, and redundancies in policy targets; and (3) assist in the deconstruction and appraisal of these complex policy targets into sets of indicators to evaluate progress.

We demonstrate an application of the third mechanism by exploring an SES approach to the development of indicators for measuring progress toward Target 14 of the CBD's current strategy (Panel 1; Figure 3). Although it is one of the few targets that acknowledge the social and ecological factors of ecosystem services, Target 14 is loosely formulated and challenging to implement. As a result, the current set of three proposed headline indicators with which to measure this target (health and well-being, biodiversity for food and medicine, and water security; UNEP 2011) are underdeveloped and rely on existing data without consideration of what measurements are required to assess progress.

Figure 3 demonstrates how an SES approach would identify a different set of measures; this (1) enables the distillation of this complex target into its component parts (eg beneficiary group and ecosystem services of relevance) and (2) begins to develop the necessary set of measures for evaluating progress. By focusing on one of the specified beneficiary groups in the target (vulnerable women), we can begin to critique and prioritize relevant HWB dimensions (basic materials, health, and security). These HWB dimensions can, in turn, be linked to the required ecosystem service benefit flows (domestic water, food, fuel, fiber, protection from natural disasters [eg floods], resource security). In this example, domestic water is selected as a priority benefit because of its relevance to women in poverty contexts and its links to both basic material needs and health dimensions of HWB; however, the SES approach could be applied for other identified benefit flows as well. Being explicit about the benefit (in this case, domestic water) helps to identify the essential services referred to in the target, which include water provision (quantity), water regulation (timing), and water purification (quality), as well as erosion control services. The SES approach also stresses the importance of other services in the bundle of services relevant to HWB of vulnerable women (eg crop production, fuelwood production), which are necessary for quantifying trade-offs with water services and their consequences for HWB. From the final list of relevant services, it becomes possible to list the social and ecological factors for each ecosystem service that will require measurement, as well as the governance and management interventions that enhance or degrade these factors. The list of relevant measures depicted in Figure 3 is long (and even longer when benefits beyond domestic water and additional beneficiaries are considered) and underscores the complexity of this policy target. However, the SES approach, when applied across all targets, will highlight the measures of relevance to other targets and thus help to ensure more efficient monitoring programs and indicator development. In fact, if Target 14 is properly appraised and operationalized, it could in essence replace many of the other ecosystem service-related targets, or at least align their monitoring programs.

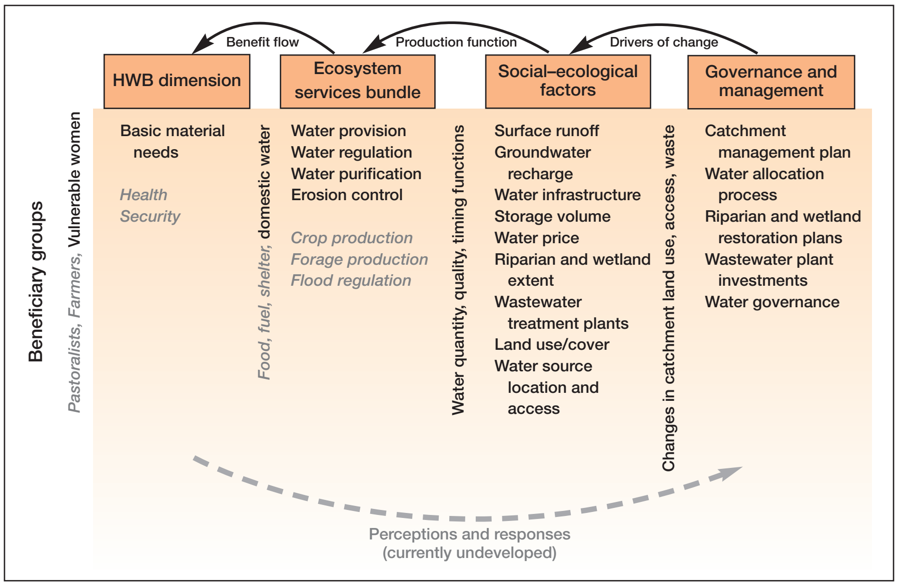

Figure 3. *Application of an SES approach to developing indicators and measures for monitoring progress toward CBD Target 14 (see Panel 1). The application starts on the left by identifying relevant HWB dimensions related to the beneficiaries identified in the target (here, vulnerable women). These dimensions include basic material needs, health, and security; a focus on the former, in turn, enables the development of a list of benefit flows relevant to material needs. From these benefits, the application takes forward domestic water and its relevant ecosystem services (related to water quantity, quality, and timing), as well as those that are co-produced by the SES and may trade off against the selected services (eg crop production, forage production). Measurements of the social–ecological factors relevant to each identified service's production function are identified. Finally, an exploration of social–ecological factors reveals management and governance interventions of relevance to the factors that require monitoring. The final link between HWB and governance and management remains uncertain and is therefore not developed in this application but could include measures of changes in attitudes to water quality or access, managers' perceptions, or national values.*

Conclusion

Considering the current limited knowledge of ecosystem services and HWB, present efforts to improve HWB through the use of ecosystem services must be "regarded as hopeful hypotheses to be tested rather than guaranteed prescriptions for success" (Carpenter *et al.* 2009). Consequently, we suggest that closer engagement with SES studies will advance our understanding of the social and ecological factors relevant to ecosystem services and HWB and will provide a more nuanced and comprehensive understanding of human–nature interactions within human-dominated environments. The strength of an SES-based approach resides in its ability to measure ecosystem services by integrating social and ecological factors, service generation, delivery, and management, as well as HWB, in a linked iterative cycle. Consequently, it provides both a theoretical and a practical set of instruments to conceptualize and understand complex SES, as well as the means to develop new targets, policy objectives, and indicators. The SES approach can assist our community in developing and testing relevant hypotheses. By learning from past successes and failures, scientists, managers, and decision makers can contribute to the ability of an SES to adapt to and shape changes – an important component of resilience in an SES (Berkes *et al.* 2003).

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WebPanel 1. Moving toward an integrated ecosystem services framework

To support and inform the complex interactions and trade-offs associated with most ecosystem services-related policies and management decisions, we propose an integrated framework that would ideally:

(1) Connect HWB to ecosystem services as products of complex SES

(2) Elucidate dynamic linkages and rates of change

(3) Provide a route so that multiple perturbations can be investigated and understood

(4) Take into account cross-scale linkages

(5) Provide a pragmatic and relevant approach to policy formulation that can form the basis for targets to be effectively linked and monitored

(6) Inform management interventions and broader policy initiatives through its predictive capabilities

(7) Integrate conservation and development policy targets