What data should we collect? A framework for identifying indicators of ecosystem contributions to human well-being

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The lack of a clear framework identifying data to link ecosystems to analyses of human well-being has been highlighted in numerous studies. To address this issue, we applied a recently developed economic theory termed "final" ecosystem goods and services – the biophysical features and qualities that people perceive as being directly related to their well-being. The six-step process presented here enabled us to identify metrics associated with streams that can be used in the analysis of human well-being; we illustrate these steps with data from a regional stream survey. Continued refinement and application of this framework will require ongoing collaboration between natural and social scientists. Framework application could result in more useful and relevant data, leading to more informed decisions in the management of ecosystems.

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Data improve our ability to manage the considerable but finite capacity of ecosystems to support diverse human activities. Yet numerous studies (eg US GAO 1981; Guerrero 2000; US GAO 2000; MA 2005; The Heinz Center 2008; Carpenter *et al.* 2009; UNEP–WCMC 2011) point to the lack of appropriate data as a major barrier to natural resource management. The problem, however, is not merely the lack of data, but also the lack of a clear framework that can be used to identify those data that will be most useful for facilitating the analysis of human well-being (Heal *et al.* 2004; Nahlik *et al.* 2012). One approach is to focus on the identification and measurement of "final" (as opposed to "intermediate") ecosystem goods and services, hereafter referred to as "final services". Final services are defined as biophysical features, quantities, and qualities that require little further translation to make clear their relevance to human well-being (Boyd 2007; Boyd and Banzhaf 2007; Fisher *et al.* 2008, 2009; Johnston and Russell 2011). Final services are those consumed, used, or enjoyed directly by humans; intermediate services are those required to produce final services. For example, for a recreational angler, stream habitat is one of many intermediate services necessary to produce fish, a final service. It is useful to think of intermediate services as being linked to final services by ecological production function models that are also sensitive to natural and anthropogenic stressors.

In a nutshell:

- People benefit from ecosystems in diverse ways, based on different "final" ecosystem goods and services
- Final ecosystem goods and services are biophysical features and qualities with clear, direct, and intuitive meaning to people
- Final ecosystem goods and services, examples of which are discussed in this paper, are the most useful links between ecosystems and human well-being
- "Intermediate" ecosystem goods and services are ones that are essential in understanding, predicting, and managing final ecosystem goods and services, but their economic value is derived from their role in producing final goods and services
- Policy makers and other consumers of natural science information should encourage and ultimately expect ecologists to communicate ecosystem status, trends, and possible futures in terms of final ecosystem goods and services

Final services are things we experience, make choices about, and that have real meaning for people. If they can be measured and quantified, they are the biophysical metrics most amenable to social evaluation. Our goal here is to identify the biophysical metrics of the final services in a particular ecological system and to describe how the data quantifying those biophysical metrics might be aggregated to facilitate social and economic comprehension. We do so by reporting on our efforts to: (1) develop a transferable process for identifying biophysical metrics that best link ecosystems to human well-being, (2) use that process to identify such biophysical metrics, and (3) illustrate and evaluate the capacity of current systems to provide information (ie indicators of these biophysical metrics), using stream ecosystems as our example. This paper is based on, and extends, two transdisciplinary workshops. The first focused on streams, the second on wetlands and estuaries (Ringold *et al.* 2009, 2011); our

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