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Quantitative criteria for choosing targets and indicators for sustainable use of ecosystems

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ABSTRACT

Wide-ranging, indicator-based assessments of large, complex ecosystems are playing an increasing role in guiding environmental policy and management. An example is the EU's Marine Strategy Framework Directive, which requires Member States to take measures to reach "good environmental status" (GES) in European marine waters. However, formulation of indicator targets consistent with the Directive's high-level policy goal of sustainable use has proven challenging. We develop a specific, quantitative interpretation of the concepts of GES and sustainable use in terms of indicators and associated targets, by sharply distinguishing between current uses to satisfy current societal needs and preferences, and unknown future uses. We argue that consistent targets to safeguard future uses derive from a requirement that any environmental state indicator should recover within a defined time (e.g. 30 years) to its pressure-free range of variation when all pressures are hypothetically removed. Within these constraints, specific targets for current uses should be set. Routes to implementation of this proposal for indicators of fish-community size structure, population size of selected species, eutrophication, impacts of non-indigenous species, and genetic diversity are discussed. Important policy implications are that (a) indicator target ranges, which may be wider than natural ranges, systematically and rationally derive from our proposal; (b) because relevant state indicators tend to respond slowly, corresponding pressures should also be monitored and assessed; (c) support of current uses and safeguarding of future uses are distinct management goals, they require different types of targets, decision processes, and management philosophies.

1. Introduction

1.1. From qualitative to quantitative criteria for indicator selection

Ecological indicators are increasingly being used in rule-based management schemes where indicator values outside their respective target ranges trigger management action. The question which properties ecological indicators should have for this purpose has often been addressed in the literature (Elliott, 2011 Queirós et al., 2016; Rice and Rochet, 2005). An example relevant for assessment and management of marine ecosystems is the set of criteria proposed by ICES (2001), which forms the basis of the Rice and Rochet (2005) criteria. These relate to concreteness, theoretical basis, public awareness, cost, measurability, representation through historic data, sensitivity, responsiveness, and specificity of indicators. A list by Elliott (2011) containing 18 criteria goes beyond the Rice and Rochet (2005) list, in requiring that indicators (and monitoring parameters) should be anticipatory, broadly applicable and integrative over space and time, interpretable, have low redundancy,

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be non-destructive, time-bounded and timely. For a detailed review and analysis of indicator selection criteria, see Queirós et al. (2016).

However, practically all published specifications of desiderata for ecological indicators and their management targets remain at a qualitative level, despite containing some quantitative components (e.g. reasonable cost in comparison with expected benefits). This has the advantage of flexibility to accommodate variation in preferences and priorities of different stakeholder groups—after all, policies manage human activities rather than the marine environment (Elliott, 2013). However, experts can vary widely in their findings when evaluating indicators according to the same criteria (Rice and Rochet, 2005), which questions the idea that such criteria provide an objective basis for indicator selection. Another disadvantage is that the scientific problem of developing indicators and monitoring programs and the scientific and societal challenge of finding appropriate target ranges for these indicators remain vaguely specified. This may lead to inconsistencies in specified target ranges, inefficient use of limited monitoring capacity, and uncertainty about the most appropriate use of research capacity for refining indicators and targets or filling potential gaps in indicator suites (Borja et al., 2012).

Ideally, a quantitative, generic, and broadly accepted framework was available for choosing indicators and setting targets, so making this a research and development task to deliver a product according to specifications, rather than a social process of finding common positions in an uncertain space. Such a quantitative framework does currently not exist. Environmental policy documents tend to specify their overall high-level objectives in a qualitative language. The purpose of this contribution is to propose, as a way forward, a quantitative interpretation of this qualitative language, which can then be tested for political acceptance. Being deliberately constructed building on just a few generic principles, our proposal is necessarily somewhat abstract and rigid, and so should not be misunderstood as a direct prescription of policy. More plausibly, it will serve as a scientifically anchored orientation point for political decision making.

As a specific policy document which is currently widely discussed in Europe, we chose to focus here on the Marine Strategy Framework Directive (MSFD; EC, 2008) of the European Union (EU). The principles being invoked for setting targets are not consistent within the community implementing the MSFD. For Cochrane et al. (2010), for example, the target is an ecosystem nearly unperturbed by humans, ICES (2014a) primarily require that ecosystem functions are not degraded, Rogers et al. (2010) and ICES (2014b) refer to abundances that can recover from perturbation or have been observed to be historically stable, and Piet et al. (2010) interpret the "safe biological limits" of fish stocks as those producing maximum sustainable yield. We shall here concentrate on policy needs under the MSFD. However, the framework we proposed might be generally useful for linking assessments of aquatic or terrestrial ecosystems to high-level policy goals.

1.2. The concept of sustainable use

The MSFD requires from EU member states to determine, in a collaborative manner, specific environmental targets and corresponding quantitative indicators that together represent "good environmental status" (GES). It defines GES as:

the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations [. . .].

Table 1
Comparison of concepts of weakly and strongly sustainable use.

	Weakly sustainable use	Strongly sustainable use
Types of relevant services	Societal choice	A priori unknown
Value of services used	Mostly known	Unknown or uncertain
Value to be preserved	Anthropogenic capital plus natural capital	Natural capital
Nature of typical target	The point corresponding to optimal long-term use	The range allowing timely recovery
Management philosophy	Optimal control (as in control theory)	Limitation of pressures

The last passage is a variation of the definition of sustainable development from the Brundtland Report (World Commission on Environment and Development, 1987):

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Important is that this definition recognizes that needs of future generations might be different from current needs. By referring to "the potential for uses and activities by [. . .] future generations", the MSFD follows this tradition. Uncertainty about future uses, and so values, of resources naturally leads to strong notions of sustainability[1] that aim at independent maintenance or enhancement of various forms of natural and non-natural capital (Figge, 2005). Contrastingly, weak sustainability permits substitution of natural with manufactured capital, implicitly assuming good knowledge of their respective future values (Figge, 2005). Correspondingly, we say here "*strongly sustainable*" for *use* of the environment that does not constrain usage choices and capabilities of future generations, and "*weakly sustainable*" for *use* that simply can be continued indefinitely in its current form (conceivable are even weaker notions). The distinction between the two concepts is briefly summarized in Table 1.

The best-known example of usage of "sustainable" in our weak sense in the marine ecology context is "maximum sustainable yield" (MSY). Management for MSY alone does not necessarily imply sustainability by the stronger definition, because changes to the wider ecosystem resulting from exploitation may be irreversible. The MSFD refers to weakly sustainable use, for example through the adjective "productive" in the GES definition above and in a clarifying Commission Decision (EC, 2010), which explicitly specifies exploitation at MSY as a target.

Our considerations here concentrate on strongly sustainable use, thus marking the limits within which weakly sustainable use options can be explored. From above considerations it follows that constraints imposed by strong sustainability will generally be weaker than those following from specific weakly sustainable use objectives; a potential source of confusion to keep in mind.

The operationalization of the strong concept of sustainable use in the context of marine management has been subject of extensive discussion in the work of the International Council for the Exploration of the Seas (ICES, 2005, 2010, 2013). ICES argued that, since the needs and preferences of future generations are unknown to us, sustainable use means not to perturb the ecosystem to such a degree that recovery from these perturbations is impossible or unacceptably slow (see also FAO, 2009). In other words, under sustainable use the system must remain capable of recovering to an unperturbed state over an acceptable time span.

[1] Others motivate strong sustainability by non-substitutability of critical natural capital, incomprehension of natural systems, irreversibility of losses, and ethically (Dietz and Neumayer, 2007).