Measuring sustainable oceanic development

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1 Introduction

As part of the post-2015 sustainable development strategy and as follow-up on the Millennium Development Goals (MDG), the UN-GA will be asked to agree on a set of Sustainable Development Goals and Targets in September 25-27, 2015. The implementation shall begin in January 1, 2016. In the meantime a multi-stakeholder process including various UN and expert meetings will advance the development of SDG indicators which will aid the implementation process by monitoring progress against the SDGs at the local, national, and global level (SDSN 2015). The OWG has suggested 17 Sustainable Development Goals (and additional 169 targets) which have been noted by the UN Secretary-General synthesis report (UN 2014, SDSN 2015). Goal 14 is devoted to the protection and conservation of the ocean: "Conserve and sustainable use the oceans, seas and marine resources for sustainable development."

Even though the proposal derived in the OWG process does not yet constitute the final definition and operationalization of the SDGs, the explicit and prominent inclusion of an *ocean* SDG is an important step forward to promoting efficient global ocean governance and other measures to enable more sustainable oceanic development. Against this background of the political process we discuss first some issues and implications of the OWG proposal with a focus on the ocean SDG. From our point of view, the inclusion of both—individual indicators and their aggregation in a meaningful composite index—would benefit the overall assessment. It would allow to implement specific priority measures but at the same time give a more comprehensive view on ocean sustainability that would encourage comprehensive policy recommendation, an objective which cannot be obtained that easily by overviewing a broad set of isolated indicators monitoring specific aspects. However, we think that modifications on the proposed composite indicator for the ocean SDG, the Ocean Health index, are necessary to obtain a meaningful and appropriate assessment of the state of the human-ocean system.

As mentioned above, indicators and indexes are supposed to serve as a management tool to implement and operationalize the SDGs and associated targets and to ensure accountability of governments and other actors against the ambition of the SDGs (SDSN 2015). The indicator report of the Sustainable Development Solution Network lists 10 principles for the identification and development of SDG indicators. In general, the indicators should be limited in number to remain manageable (up to 100 global reporting indicators), should be science-based and forward-looking to properly take into account future developments (e.g., population growth or technological advances), should be constructed from established data-sources to enable continuous and reliable measurement over time, and should have clear policy relevance. The latter is supposed to be achieved by using indicators which are simple to compile and easy to interpret. Furthermore, it is suggested that composite indices should be avoided because "they require more complex data collection methods, often rely on imputation for missing values, and arbitrary weighting. Moreover, composite indices do not lend themselves easily to policy recommendations…" (SDSN 2015, p.10). However, exemptions have been suggested regarding the use of composite indicators for certain goals.

Among those exemptions could be the ocean SGD 14. The working draft report by the SDSN suggested two indicators to measure oceanic sustainable development at the global level, Indicator 82, the Ocean Health Index (OHI) (Halpern et al. 2012, www.oceanhealthindex.org), a composite index, and Indicator 83, Proportion of fish stocks within safe biological limits (MDG Indicator). The argument brought forward for the inclusion of a composite index for assessing the ocean SDG is that the complexity of the human-ocean system cannot be captured by (a limited number of) single variables and that therefore a composite measure is necessary. In addition to these two main indicators, further indicators or indicator themes to be applied at the national level are discussed: 14.1 Area of coral reef ecosystems and percentage live cover, 14.2 Indicator on the implementation of spatial planning strategies for coastal and marine areas, 14.3 Eutrophication of major estuaries, 14.4 Share of coastal and marine areas that are protected, 14.5 Use of destructive fishing techniques, 14.6 Indicator on access to marine resources for small-scale artisanal fisheries, and 14.7 Indicator on transferring marine technology. Additionally, to these indicators summarizes under the ocean SDG, there exist of course other indicators under other goals with relevance for ocean health, like for example Indicator 86 which is supposed to measure endangered species or Indicator 87 which measures marine protected areas, both as part of SDG 15.

In general, it appears surprising that composite indices are supposed to be avoided but that instead a large number of stand-alone indicators should provide the backbone of the operationalization of the SDGs with the argument that such an approach results in clear(er) policy recommendations. This argument can be disputed—in particular against the aim of guiding policy towards sustainable development.

First, Pintér et al. (2005) and Kopfmüller et al. (2012) argue that a small set of indicators has greater relevance for decision-makers. For that reason, they argue, headline indicators have gained a more prominent role in the literature on sustainability assessment. There is a wide agreement that a broad set of variables and therefore possible indicators should be considered at the initial level. However, based on this initial collection a transparent and consistent approach to select those indicators "that best reflect the value, defined as the welfare effect, of the various components of national wealth" (Alfsen and Greaker 2007, p. 607) is needed. For example, in assessing the sustainable development of Santiago de Chile, Kopfmüller et al. (2012) discuss initially 120 indicators, ending up with 12 "headline indicators" for the sustainability assessment of the city.

Second, policies for sustainable development often face trade-offs between different sustainability objectives: actions have a positive influence on some resources and services (measured by a specific indicator) but a negative one on others (measured by a different specific indicator). In such a situation, the broad set of (potentially diverging) indicators does not directly indicate what is a suitable policy. If there is a widely agreed way of aggregating these "conflicting" indicators, the resulting composite index might be helpful (e.g., Rickels et al., 2014). The composite or aggregate index suggested for the ocean SDG, the OHI, implicitly considers a rather extreme type of aggregation ('normative frame'), implicitly assuming unlimited substitution possibilities among the various goals. Thus, the OHI satisfies only a concept of weak sustainability, which may be a questionable approach given the complex interactions in the human system (Rickels et al. 2014, Brandi 2015).

In this paper we will outline some thoughts and suggestions for a more appropriate concept of measuring ocean health by a composite index. In Section 2 we provide a review of the currently discussed composite index, the OHI. In Section 3 we explain how sustainable development can be measured for the ocean and in Section how a meaningful index could be constructed. Section 5 concludes and provides our suggestion.

2 The Ocean Health Index

The OHI aggregates ten ocean-related societal goals to represent the ecological, social, and economic benefits of the ocean (Halpern et al. 2012). The OHI is calculated at the regional and global level by taking the weighted arithmetic average score of these goals. The ten ocean-related societal goals included in the ocean health index are 1) 'Artisanal Fishing Opportunities', 2) 'Biodiversity' ('Species' and 'Habitats'), 3) 'Coastal Protection', 4) 'Carbon Storage', 5) 'Clean Waters', 6) 'Food Provision' ('Wild Caught Fisheries' and 'Mariculture'), 7) 'Coastal Livelihoods&Economics' ('Livelihoods and Economics'), 8) 'Natural Products', 9) 'Sense of Place' ('Iconic Species' and 'Lasting Special Places'), and 10) 'Tourism&Recreation' (Halpern et al. 2012). Some of these goals are aggregates of sub-goals themselves, as indicated by the terms in the parenthesis above. The indicators for the goals and sub-goals do not only take into account the present, but also the future state, the latter being derived from the assessment of the pressures on, and the resilience of, the specific goal. Consequently, not only the comparison of the OHI over time but also its value at a single point in time provides information on the sustainability of the human-ocean system.

The OHI was first released in 2012 with a ranking of 171 coastal states and regions based on the condition of their marine ecosystems in their EEZs. The index is updated annually, providing therefore by now information on ocean health from 2012 until 2014 (www.oceanhealthindex.org). In 2013 the index was extended to rank a total of 220 countries/islands compared to 171 countries/regions in 2012. Previously aggregated regions (like, say, the USA Pacific Uninhabited Territories) have been evaluated and assessed separately. Consequently, the index in 2012 has also been recalculated for the lower level of spatial aggregation. In 2014 the index was further extended to provide information on Ocean Health around Antarctica and for the high seas. Furthermore, since 2014 several independent assessments have been published which apply the concept of the OHI to assess ocean health at the national or regional level. Independent assessments at the national level have been published for Israel, the Fiji Islands, and Brazil, including also results on the regional state level, an independent assessment at the regional level has also been published for the US West coast (references). Further independent assessments at the national and regional level are underway.

Irrespective of its role in the assessment of the ocean SDG, the OHI represents a seminal contribution to better monitoring, understanding and managing of the human-ocean system. However, as mentioned already before and detailed above, it should only be used with caution to identify sustainable oceanic development as the applied aggregation method assumes unlimited substitution potential and satisfies only a concept of weak sustainability (Rickels et al. 2014, Visbeck et al. 2014). Furthermore, the selection of variables to measure the performance in individual goals is not based on an overall concept which would account for the influence of the various oceanic resources and assets to sustainability.

3 Measurement of sustainable development: Concepts of weak and strong sustainability

Sustainable development requires that wealth, in a comprehensive sense, will not decrease over time (Arrow et al. 2003). From an economic perspective, non-decreasing inclusive wealth requires non-decreasing production (whereby the term production also includes natural and non-market production) which in turn requires that nature's and the economy's production potential—its endowment with capital stocks—is maintained constant or growing over time (e.g., Pearce 1993, Smith et al. 2001, Arrow 2003, Dasgupta 2009). This concept is based on broad definition of capital stocks, not being restricted to man-made capital but also including human, social and in particular environmental capital stocks.

Given a meaningful classification of capital stocks exists—which is still not the case for oceanic resources and services—the sustainability concept needs to assess the aggregated change in capital stocks to assess whether the production potential is sustained. Obviously, situations in which all capital stocks increase can easily be identified as sustainable development, like it is the other way around when all capital stocks decrease. However, in situations where some capital stocks increase while other decrease, attention needs to be paid to the substitution potential among them—which may be limited for ecological or technical reasons or because social preferences only allow substitution to a limited extent (e.g., Bartelmus1989, Daly1991, Victor1991). Varying degrees in substitution potential are reflected by the distinction between *weak* and *strong* sustainability.

The concept of *weak sustainability* allows for unlimited substitution and requires that the aggregate of the various capital stocks, valued with their respective (shadow) prices does not decline (e.g., Pearce et al. 1989, Daly and Cobb 1989, Hartwick 1990, Hamilton 1994).[1] A scarce capital stock results in a high shadow price and obtains therefore a higher weight in the aggregated composite of capital stocks (e.g. Dasgupta 2009). The OHI represents such a concept of weak sustainability, however, the applied weights are constant, and thus do not reflect relative scarcities as shadow prices would do. In particular, they are not derived from a welfare concept and the resulting value function. They therefore do not properly represent the contribution of the corresponding capital stock (goal) to wealth, except one is willing to assume unlimited substitution possibilities between the different goals. Moreover, the main results are derived by assuming equal weights for all goals.[2] The computation of the shadow

[1] The shadow price reflects the influence of marginal changes in the corresponding capital stock on the objective function, i.e. global wealth.

[2] Halpern et al. (2012) have carried out sensitivity analyses with respect to different weights for the calculation of the OHI in 2012.

prices for non-market based capital stocks like social or environmental capital stocks will always be highly uncertain, in particular with the respect to the human-ocean system where various interactions and feedbacks are not properly understood. Nevertheless, improved understanding and modelling could contribute significantly to a better representation of relative scarcities of the different capital stocks. However, even with more appropriate shadow prices, in a concept of *weak sustainability* services stemming from machinery and artefacts can for example replace services of natural capital (at the rate of their corresponding shadow prices).

Facing such complex ecological-human interactions like the human-ocean system, it is crucial to pay attention to the limits of substitution between the various capital stocks—otherwise sustainable development trajectories might be identified that do not adequately account for the underlying trade-offs (e.g., Dasgupta and Heal 1979, Pearce et al. 1989, Victor 1991, Ekins et al. 2003, Ayres 2007, Visbeck et al. 2014, Rickels et al. 2014). For that reason, the concept of *strong sustainability* does not allow for substitution between the various capital stocks beyond a critical limit. Accordingly, the requirement is that the remaining stocks of natural (oceanic) capitals would need to be maintained at levels above critical minima independently of the way in which other (man-made) capital stocks develop.

One could argue that the approach outlined by the OWG follows such a concept of strong sustainability because by opposing in general to the use of composite indices achieving sustainable development requires based on their approach that all capital stocks (quantified by indicators) have to be at least maintained at the current level. However, that would for example imply that in a situation where all but one indicator improve (which would be an unlikely success) the goal of sustainable development would not be achieved. Furthermore, as argued above, policies often affect various indicators in opposite directions (e.g., job creation versus nature conversation), making it practically impossible to provide policy advice based on the indicator set given no policy exist that improves all indicators. Furthermore, one needs to bear in mind that strictly following a concept of strong sustainability could actually result in hindering the application of effective environmental (marine) policies. For example, closing a certain fisheries for a limited period of time could violate the concept of strong sustainability because social or economic capital stocks would shrink—indicating also that sustainability is very different concept than optimality.

Obviously, *weak* and *strong* sustainability represent two extreme cases, while in reality the appropriate level of substitution potential can be expected to be between these two extremes and differ in dependence on the characteristics of the underlying capital stocks to be assessed (e.g., Bateman et al. 2011, Rickels et al. 2014). Dealing with this different requirements and varying degrees of substitution potential among different goals can be achieved by applying a nested index for measuring sustainable development. Applying a nested index with various levels allows for consideration of different substitution possibilities at different levels by, for example, first aggregating capital stocks with better substitution possibilities (Dovern et al. 2014).

Furthermore, developing suitable indicators to measure the sustainable (oceanic) development could be supplemented by inclusion of *safe minimum standards* (Ciriacy-Wantrup 1952). Defining s*afe minimum standards* implies that actions are restricted so that ecosystems are kept clear of critical states. The argument is that only relatively small effort (management and costs) are necessary to avoid potentially large losses associated with the degradation of the ecosystem (Ciriacy-Wantrup 1952). Furthermore, it has been argued that *safe minimum standards* provide more latitude for risk assessment and trade-offs than the rules of *strong sustainability,* even if both approaches may converge toward similar objectives (Visbeck et al. 2014). In assessing and measuring sustainable (oceanic) development, safe minimum standards can be introduced by defining lower bounds for certain capital stocks. The assigned value for the corresponding capital would drop to zero if the measured capital stock falls short of this bound (Heal 2009). Accordingly, the overall score would also drop to zero if substitution elasticities are assumed to be below 1 albeit without dominating the index score if the state is still in good condition, which would in turn result from significantly increasing the weight of the goal (Heal 2009, Rickels et al. 2014).

4 Construction of a composite index to measure sustainable development

Before discussing the aggregating of indicators to an index one needs to bear in mind that already the selection of appropriate indicators is an important step in achieving a meaningful measure for sustainable development. The selection is usually restricted by data availability. In particular for environmental capital stocks the actual real influence on wealth and/or sustainable development is not reflected in (market) values. These assets are thus measured by related indicators. On the other hand, the selected indicators should be related to policy measures/targets and therefore suitable for influencing the decision-process. Accordingly, beyond the question of appropriate weighting (using shadow prices) already the selection of indicators is a normative choice (e.g., Krellenberg et al., 2010). There exist no unambiguous rules for selecting indicators (Böhringer and Patrick 2007). For that reason the process of selection indicators should be done in transparent manner, usually structured by selection a rather large set of possible indicators from which one selects then appropriate ones according to some accepted method. Ideally, the selection is supported by empirical analysis on the historical influence of the indicator on the desired objective, the historical influence of policy measures on the indicator, and the correlations of the various indicators. While the first and second recommendation cannot always be achieved that easily, the third step can be carried out quite easily. High correlation among indicators implicitly influences the weighting applied in a composite index. However, the problem associated with correlation among indicators is not restricted to composite indexes. Also in case of using a series of stand-alone indicators for assessment, neglected correlation can yield biased results, indicating either very successful or very unsuccessful sustainable development in dependence of one underlying (principal) component.[3]

Having a set of indicators, I_i, the aggregation into an index is usually amplified by the different measurement units of the variables which makes them non-comparable (e.g., number of jobs in the fishery industry versus carbon uptake in Gt C per year). Given that all selected indicators are ratio-scale measurable, a meaningful aggregation can be achieved by applying a (weighted) geometric mean (e.g., Ebert and Welsch, 2004). Here, meaningful means that the ordering for the states or paths obtained from the index is not influenced by the measurement units in which the indicators are expressed (e.g., Ebert und Welsch 2004, Böhringer and Patrick 2007).

[3] Principal component analysis is a potential empirical analysis to be used to identify the main drivers for development.

However, using a geometric mean allows only for an ordinal and not a cardinal comparison of the underlying states and furthermore precludes investigation of different levels for the substitution possibilities. For that reason the indicators are usually transformed so that all of them are fully comparable. For example, Halpern et al. (2012) assume for the construction of the OHI that goal-specific scaling factors exists (they use the goal-specific best-value) and obtain individual goals (i.e. indicators) ranging between 0 and 100. Having such ratio-scale measurable, fully comparable indicators, meaningful aggregation into an Index, X, is obtained by applying generalized means (Blackorby and Donaldson, 1982):

$$X(a_i, I_i, \sigma) = \left(\sum_{i=1}^{N} \alpha_i I_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \quad (1)$$

with weights $\alpha_i > 0$ and $0 \leq \sigma \leq \infty$. The parameter σ quantifies the *elasticity of substitution* between the different indicators (Solow 1956, Arrow et al. 1961, Armington 1969). Consequently, we obtain a full class of specific functional forms for the index depending on σ, which we can denote therefore by $X(\sigma)$ for the case of a given set of indicators and weights.

As mentioned before, the indicators I_i can by themselves being constructed as a composite index like the one given in (1). A neat example would be to measure among other factors the influence of air quality. Consequently, one could construct a composite indicator for air quality which aggregates the concentration of nitrogen dioxide, ozone and particulate which enters then the overall composite (nested) index. Such an approach allows for aggregating first more detailed indicators which might have a higher substitution potential among each other than the overall underlying influence (air quality) on the objective with the other overall influences. Furthermore, such an approach with higher levels of substitution on the lower levels also reduces the influence of measurement errors (Dovern et al. 2014).

For the aggregation at the “top” level of the nested index, the requirement of relatively strong sustainability, requires choosing a value for σ below 1 (e.g., Gerlagh and van der Zwaan 2002, Heal 2009, Bateman et al. 2011, Traeger 2013). More specifically, Sterner and Persson (2008) suggest using $\sigma = 0.5$ in their study of the human-climate system. In contrast, Halpern et al. (2012) have chosen the extreme case of $\sigma \rightarrow \infty$ (unlimited substitution possibilities) which results in the arithmetical weighted mean

$$I(\infty) = \sum_{i=1}^{N} \alpha_i I_i. \quad (2)$$

With such a specification of σ, the distribution of scores over the different indicators only has any bearing on the value of the ocean-health index to the extent that the constant weighing factors may differ.

5 Conclusion and Recommendation

The inclusion of an *ocean* SDG in the post-2015 development process is a tremendous step in achieving more efficient ocean governance and sustaining a healthy human-ocean system. The outlined approach by the OWG provides an excellent starting point for finalizing the SDG concept to be launched in January 2016. However, meaningful measurement and sound derivation of (marine) policy advice requires some modifications on the currently outlined concept.

Even though the OWG output does not support the inclusion of composite indicators, the ocean SDG is among the exemptions, proposing to use the Ocean Health Index. The main argument brought forward for the inclusion of the OHI is that the complexity of the human-ocean system cannot be captured by single variables. However, even though we agree that a composite index is useful, we think that the method of aggregation applied in the OHI is debatable when it comes to capturing the complex dynamics of the various interactions and feedbacks involved in the human-ocean system. The reason is that OHI satisfies only a concept of weak sustainability which allows for unlimited substitution possibilities among the various indicators. Furthermore, the applied weights for the different indicators are not derived from a comprehensive (blue) wealth concept and do for this reason not represent the *real* scarcities being associated with the underlying goals.

In the current OWG proposal, the indicators proposed for the ocean SDG additionally to the OHI, cover aspects and assets which are already included in the OHI (e.g., sustainable fisheries, access to artisanal fishing opportunities or the influence of marine protected areas). Consequently, we think that the approach outlined for the ocean SDG provides already a structure for a meaningful measurement of SDGs in general, namely a) a selection of indicators which can be monitored individually and b) an aggregation of these indicators in a composite indicator to assess how the overall states develops (without the need to collect further indicators). However, the composite indicator should satisfy a concept of relatively strong sustainability. Using a nested structure for the composite indicator and including safe minimum-standards would be further options to achieve a meaningful measurement of the complex ecological-human interactions in the human-ocean system.

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