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Keywords: Sustainable Development Goals, Indicator Selection, Composite Indicators, Ocean

JEL classification: Q01, Q56

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Indicators for Monitoring Sustainable Development Goals: An Application to Oceanic Development in the EU

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The 2030 Agenda for Sustainable Development that includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets could be a step forward in achieving efficient governance and policies for global sustainable development. An essential element will be the global indicator framework for monitoring and assessing progress over and against both the overall goals and the specific targets and to guide policy towards sustainable solutions. In the debate over the current indicator framework, little attention is devoted to conceptual issues. Here, we argue that the inclusion of composite indicators as complements to the single indicator approach could support the overall assessment process without necessitating any significant changes to the currently proposed indicator base. While the individual indicators remain the backbone of the indicator framework, allowing a detailed assessment of specific policy measures, the composite indicators can be used to explicitly assess trade-offs between policies. Our illustrative investigation of the sustainable oceanic development of EU coastal states highlights how much a comprehensive assessment can benefit from the additional inclusion of composite indicators.

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1 Introduction

On September 25, 2015, the 193 members of the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development. This agenda includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets (UN 2015). As part of the sustainable development strategy, a set of global indicators will be used to monitor and assess progress over and against both the overall goals and the specific targets. The Inter Agency and Expert Group on SDG Indicators (IAEG-SDGs) develops the global indicator framework in cooperation with the UN Statistical Commission. The IAEG-SDGs was established by the UN Statistical Commission (UNSC) at its 46th session (March 3-6, 2015). The UNSC has received several lines of inputs. For example, the Sustainable Development Solution Network (SDSN) submitted a report (SDSN 2015) that proposes 100 global monitoring indicators, accompanied by suggestions for complementary national indicators. Simultaneously, a preliminary list of 300 indicators was launched (about two indicators per target). Since then, the proposed indicators have been submitted to an open forum for wide consultation. Countries, regional and international agencies, civil society, academia, and the private sector are invited to comment and express their views. This discourse has generated suggestions, comments, and other inputs which provided the basis for the further development of the indicator framework at the second meeting of the IAEG-SDGs (October 26-28, 2015). The global indicator framework is scheduled to be adopted by the Economic and Social Council and the General Assembly during their respective meetings in March 2016 (UN 2015).

The large number of indicators is considered necessary to fulfill the criteria of being useful in a management context and for the purpose of (statistical) capacity building (UN 2015). At the same time, the large number of indicators amplifies the effort that is needed to evaluate the overall success in achieving sustainable development. Not surprisingly, a major concern in the current discussion about the monitoring process is that clear policy guidance towards achieving an SDG is potentially blurred by the number of targets and the even larger number of indicators. This could lead to an arbitrary application of management measures focusing only on less critical or easy to achieve targets (Loewe and Rippin 2015). Facing these competing aims, this paper discusses to what extent the inclusion of additional, scientifically sound composite indicators can improve the validity and policy relevance of the current SDG measurement and assessment framework. We discuss in how far different concepts of sustainable development are already implicitly embedded in the proposed framework, arguing that the debate about the inclusion or omission of certain indicators is a discussion about weights on specific targets and very similar to the choices that have to be discussed in the case of constructing composite indicators. Specifically, we analyze in detail the indicators that are currently discussed in the context of SDG 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development.* In this way, we exemplarily discuss the use and advantages of composite indicators and emphasize the challenges currently faced by IAEG-SDGs, the UN Statistical Commission, and further stakeholders. We apply the proposed approach to assess the sustainability of ocean and maritime development of EU coastal states and show how sustainable development assessment can benefit from the additional consideration of composite indicators.

2 Measuring (Oceanic) Sustainable Development

Sustainable development requires that wealth, in a comprehensive sense, will not decrease over time (Arrow et al. 2003). Phrased in the terms of the famous formulation of the United Nations World Commission on Environment and Development it requires that a development is achieved "which meets the needs of the present generation without compromising the ability of future generations to meet their needs" (Brundtland et al. 1987). However, no unique or ideal approach exists for selecting a measurement framework to characterize such developments. Consequently, the different actors involved (e.g., politicians, statisticians, or academics) put different weights on specific dimensions of.[1] From an academic perspective, for instance, a logical approach suggests to start with the derivation of a sound theoretical concept of sustainability which forms the foundation for the design of the measurement framework. In subsequent steps, this framework might then be adjusted to respond to or comply with practical requirements.

2.1 The Capital Approach as (Economic) Concept for Sustainable Development

The capital approach is probably the most prominent approach to think about issues of sustainability in the (economic) academic literature. It is based on the idea that the resource assets (capital stocks) left behind determine the well-being of future generations (UNECE 2014). More formally, non-decreasing comprehensive wealth requires that the production potential of nature and the economy—the endowment with capital stocks—is constant or growing over time (e.g., Pearce 1993, Smith et al. 2001, Arrow 2003, Dasgupta 2009). Here, the term production also includes natural and non-market production. Accordingly, this concept is based on a broad definition of capital stocks which includes not only man-made (economic) capital but also human capital, social capital and, in particular, environmental capital stocks. Although using the term "capital stock" requires some caution in debates outside the academic circle (Radermacher 2005), it provides a sound concept to formalize issues of (dis-)investment in the context of (natural) resources and is deeply rooted in economic theory. The concept has been adopted, for example, in the Report by the Commission on the Measurement of Economic Performance and Social Progress (the Stiglitz-Sen-Fitoussi Report), in the Reports of the UNECE/Eurostat/OECD Working Group on Statistics for Sustainable Development, and in the European Seventh Environmental Action Programme to 2020 (UNECE 2014).

The capital approach faces some challenges regarding its practical implementation, which have not yet been fully tackled. Even though the United Nations System of Environmental-Economic Accounting (SEEA) provides formal definitions and guidance for measuring natural capital stocks, the (physical) quantification of the stock's size and the quality of many natural resources is very uncertain and remains only crudely measured at best (e.g., Fenichel and Abbott 2014). This holds in particular for the multitude of oceanic resources (e.g., Visbeck et al. 2014). The comprehensive blue wealth of the oceanic capital stock, for instance, has not yet been properly assessed (with the exception of case studies on fisheries, see Fenichel and Abbott 2014). Furthermore, formal definitions of human and social capital are still not available outside the academic literature (UNECE 2014). Consequently, the capital approach is interpreted as an organizing framework, which requires the identification and selection of non-monetary (physical) indicators to approximate the size of capital stocks and their changes over time (e.g., Radermacher and Steuerer 2014).

In the current debate about appropriate indicators, a further classification of indicators is obtained from the pressure-state-response (PSR) framework (OECD 1993). In a nutshell, the PSR framework distinguishes between a) indicators that measure human activities like for example nutrient pollution that exert *pressure* on natural systems, b) indicators that measure the state of environmental systems like the eutrophication level of a lake (which is affected by pressures), and c) indicators that measure human responses to changes in pressures or state like for example the establishment of a regulatory framework or other policy instruments to limit pollution. In the capital approach, the capital stocks are measured by state variables so the capital approach would require state indicators.

[1] For a discussion about the involvement of different actors, see, for example, Radermacher (2005).

2.2 Assessing Sustainable Development with (Composite) Indicators

Having a set of non-monetary indicators as proxies for the capital stocks, it remains an open question how sustainable development should be assessed when certain indicators increase while others decrease. Obviously, situations in which all indicators increase can easily be identified as sustainable development. Likewise, an unsustainable development is easily identified when all indicators decrease. However, the typical situation is that some indicators increase while other decrease. In such a situation, sustainable development assessment is not straightforward. Having an indicator set, like in the current outline for the SDGs, a qualitative assessment and discussion is required to assess the overall development. Such a qualitative assessment includes an implicit weighting of indicators. It also includes implicit assumptions on the substitution possibilities between the targets measured by the different indicators. These substitution possibilities determine how an increase in one indicator can compensate for a decrease in another indicator. Consequently, the assessment based on indicator sets involves several normative judgements and decisions which are seldom transparently explained and displayed.

Using composite indicators that comprise indicators for several targets demands an explicit treatment of the trade-offs. Prominent examples for composite indicators are the Human Development Index[2] (HDI) and, in the context of sustainable ocean development, the Ocean Health Index[3] (OHI). The HDI is computed as the geometric mean of three sub-indicators which themselves are also composite indicators, reflecting the areas of health, education and economic development. The OHI is computed as the arithmetic mean of ten different indicators that measure natural, economic, and social aspects of ocean health. Obviously, the aggregation of indicators into a composite indicator requires some kind of weighting scheme and an explicit specification of the substitution possibilities.

The explicit specification of those parameters allows for a clear distinction between *weak* and *strong* sustainability concepts. The concept of *weak sustainability* allows in principle for unlimited substitution and requires that the aggregate of the various indicators does not decline (e.g., Pearce et al. 1989).[4] In contrast, the concept of *strong sustainability* does not allow for substitution between the various targets at all. Obviously, the two assumptions of no substitution possibilities on the one hand and of perfect substitution possibilities on the other hand represent two extreme cases. In reality, the appropriate level of substitution potential can be expected to lie between these two extremes and is likely to differ depending on the characteristics of the underlying capital stocks (e.g., Bateman et al. 2011).

The OHI implicitly assumes an elasticity of substitution of infinity and, therefore, follows a concept of weak sustainability with unlimited substitution possibilities (Rickels et al. 2014). The HDI implicitly assumes an elasticity of substitution of 1 and is, thus, by construction less optimistic regarding the substitution possibilities than the OHI. Moving even more in the direction of strong sustainability requires choosing a substitution elasticity below 1 (e.g., Gerlagh and van der Zwaan 2002, Heal 2009, Bateman et al. 2011, Traeger 2013).[5] Facing varying degrees of substitution potential among different indicators, aggregation could be improved by constructing a nested/multi-layered composite indicator for measuring

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[2] http://hdr.undp.org/en/content/human-development-index-hdi.

[3] www.oceanhealthindex.org.

[4] In the context of the capital approach the aggregation of capital stocks should be obtained by using shadow prices (e.g., Pearce et al. 1989, Daly and Cobb 1989, Hartwick 1990, Hamilton 1994). Shadow prices reflect (i) the absolute scarcity of resources, which can be quantified by economic-scientific approaches, (ii) the expectations about future management of human-made and natural capital stocks, and (iii) normative sustainability objectives. A scarce capital stock results in a high shadow price and, in turn, obtains a higher weight in the aggregated composite of capital stocks (e.g., Dasgupta 2009). However, scientific approaches to properly determine such shadow prices are not yet available for several domains of natural, human, and social capital. Furthermore, the computation of the shadow prices for non-market based capital stocks (like social or environmental capital stocks) is highly uncertain.

[5] For instance, Sterner and Persson (2008) suggest using 0.5 in their study of the human-climate system.

sustainable development. Applying such nested structure with various layers (like the HDI) allows considering different substitution possibilities at different levels. For example, indicators with better substitution possibilities could be aggregated in a first stage (Dovern et al. 2014). Even though such a process of designing a (possibly nested) composite indicator can be supported by empirical analysis (e.g., correlation or principal component analysis), the final decisions about weights require normative judgement. This is not different to the case of the selection of individual indicators.

Nevertheless, a major argument brought forward against the use of composite indicators is that no scientifically sound weighting scheme exists (e.g., UNECE 2014). For example, the OHI is not based on derived (shadow price) weights but based on equal weights for all individual indicators for ocean health.[6] However, the same criticism applies to the design of any indicator set: including an additional indicator effectively results in a reduction of the weights given to all or some of the existing indicators while the opposite is true in the case of excluding certain indicators. In that case, the neglected indicators have no weight and the relative weights of other indicators change. This is so because in reality each indicator correlates to some extent with others, and leaving one indicator out that strongly correlates with a second one, but only weakly with a third one, implicitly puts more weight on the third one relative to the second one. The current discussion about the appropriate number of indicators for measuring the SDGs is, therefore, actually a discussion about implicit weights given to different indicators. In this discussion, different stakeholders, by requesting or opposing the inclusion of certain indicators, argue for different weights reflecting their preferences or prior beliefs. For example, the SDSN (2015) proposed 100 global indicators of which several are assigned to more than one target, implicitly increasing the overall weight of those indicators. Consequently, and abstracting from the hypothetical case in which proper shadow prices are available, explicit and implicit weighting is always a central issue for sustainable development assessment. Providing maximum transparency about the overall design of the assessment framework is of utmost importance in any assessment framework. Communicating transparent and explicit weighting schemes for composite indicators provides clear information and rules for the assessment of trade-offs. In contrast, facing "just" a set of indicators allows prioritizing and emphasizing those indicators with a rather good performance (i.e., adjusting ex post the implicit weighting scheme).

2.3 A Note on Uncertainty, Irreversibility, and Thresholds

Measuring the aggregated change in resources has been criticized for dealing insufficiently with uncertainties, irreversibility or tipping points (Radermacher and Steuerer 2014). The human-ocean system is a good example for a highly complex system for which humankind does not yet properly understand all interactions and feedbacks involved. Science is still very limited in its ability to reproduce the non-linear and interactive system dynamics that characterize the ocean (Visbeck et al. 2014). Even though a comprehensive treatment of this issue is beyond the scope of our article, it should be noted that by the inclusion of safe-minimum standards the indicator framework can be adjusted to incorporate such kind of boundaries for development. Safe-minimum standards for ecosystem services require avoiding potential critical zones for the state of these ecosystems (Ciriacy-Wantrup 1952). Such minimum standards can easily be introduced by defining lower bounds for certain indicators below which the score drops to zero or other forms of non-linearities kick in (Heal 2009, Baumgärtner et al. 2015). Consequently, a particular indicator could influence the overall score more heavily once it undershoots its minimum standard (moving the overall indicator to zero in the extreme case and if substitution elasticities are assumed to be below 1), without, at the same time, dominating the overall score as long as the underlying state is in good condition (Heal 2009, Rickels et al. 2014). The idea of safe-minimum standards has been further developed by Baumgärtner and Quaas (2009) in the context of uncertainty. They consider not only

[6] In addition to the main calculation with equal weights, Halpern et al. (2012) include a sensitivity analysis in which they consider different weighting schemes.

thresholds but also the probabilities with which the corresponding thresholds might be violated. Consequently, the suggested framework allows not only assessing the sustainability of development but also the viability of the overall system (De Lara and Doyen 2008).

3 The Ocean SDG: a Case Study for the European Union

To illustrate challenges for selecting appropriate indicators and the possibility to use (composite) indicators, we discuss an indicator framework to measure sustainable oceanic development of EU coastal states.

3.1 Selection of Indicators

There exist no unambiguous rules for selecting indicators (Böhringer and Patrick 2007). Thus, the process of selecting indicators for measuring the success in SDG achievement should be done in a transparent manner. There is a wide agreement that a broad set of potential indicators should be considered at the initial stage. From these, the appropriate indicators should be selected according to some transparently explained method (e.g., Pintér et al. 2005, Kopfmüller et al. 2012).[7] We base our indicator selection on the preliminary indicator set proposed for SDG 14 by the UN Statistical Commission (2015), considering also the comments from the open consulting on the proposed indicators (IAEG-SDGs 2015). The SDG 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development* contains 10 targets (14.1-14.7 and 14.a-14.c), each including two proposed indicators. Below, we discuss our selection of indicators for each target. Table A1 in the Appendix summarizes the indicators proposed by the UN Statistical Commission and our selection.

Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

UNSC proposed Indicator 14.1.1: Fertilizer consumption (kg/ha of arable land)

Managing nutrient pollution to prevent eutrophication is an important element of sustainable oceanic development (e.g., Selman et al. 2008, Visbeck et al. 2014). However, the proposed indicator has so far been discussed controversially in the open consulting forum. The indicator is criticized for being a poor proxy for marine contamination, leaving out other sources of pollution arising from, for example, insufficient discharge treatment or oil spills and for focusing only on agricultural inputs (IAEG-SDGs 2015). Furthermore, monitoring fertilizer consumption as an indicator for sustainable ocean development obviously conflicts with other sustainability targets addressing food production and poverty reduction. Low levels of nutrient input in agriculture could actually indicate a situation of soil nutrient depletion and therefore of unsustainable agricultural practice. Accordingly, the stand-alone information provided by the indicator fertilizer consumption can only provide insights for assessing sustainable development if considered in relation to other indicators. The UN Statistical Commission proposed to include instead two other indicators, an *Index of Coastal Eutrophication* (ICEP) as a state indicator and *Nitrogen Use Efficiency* as a (composite) pressure indicator.

The EU Marine Strategy Framework Directive (enforced 2008 and transposed into national legislation by 2010) includes 11 descriptors (i.e., a composite assessment of several indicators) to measure the environmental status of the European maritime regions and one descriptor addressing the issue of eutrophication. The latter one is based on eight indicators (such as, for instance, the concentration of

[7] For example, in assessing the sustainable development of Santiago de Chile, Kopfmüller et al. (2012) initially discuss 120 indicators, ending up with 12 (headline) indicators to measure the sustainability of the city.

nutrients in the water column) and several of these indicators are already evaluated within the regional sea protocols (OSPAR and HELCOM). However, only a small set of countries can provide such detailed measures of the regional sea conditions (with respect to nutrient pollution), hampering the international comparison of sustainable development. Furthermore, a pressure indicator like fertilizer consumption is more closely connected to actual policy measures (in comparison to such state indicators) and one could argue that it is more appropriate in measuring efforts for sustainable development.

Eurostat provides also information about *Gross Nutrients Balance (kg/ha of Agricultural Land)* for nitrogen (N) and phosphorus (P). Nutrient input is measured in relation to nutrient output, taking into account the input from fertilizers, non-agricultural emissions, biological nitrogen fixation, seed and plant material along with feedstuff from domestic production and from imports. In line with the German indicator report for sustainable development we choose the ***Gross N Balance*** as our first indicator, reflecting marine nutrient pollution.[8]

UNSC proposed Indicator 14.1.2: Plastic materials entering the ocean from all sources (metric tons/year)

Increasing amounts of plastic waste entering the marine environment are a major threat for sustainable ocean development because of their persistence and negative impacts on the marine ecosystems (e.g., Thompson et al. 2009). Accordingly, the underlying subject is considered to be highly relevant in the open consulting forum. It is suggested, however, to focus stronger on marine debris and beach litter density (IAEG-SDGs 2015). The UN Statistical Commission proposes *Floating Plastic Debris* as a new indicator, using (model) data from the *Transboundary Water Assessment Programme*. Again, such a state indicator is less closely connected to actual policy measures, complicating the monitoring of progress in controlling marine debris. Accordingly, the UN Statistical Commission recognizes that additional indicators might be suitable to measure what member states are actually doing to achieve this target.

Jambeck et al. (2015) provide estimates for the mass of land-based plastic waste entering the ocean and show that the quality of waste management is an important indicator in determining the amount of uncaptured (plastic) waste available to become plastic marine debris. For our illustrative investigation of sustainable oceanic development in the EU we choose two indicators (2.a and 2.b), ***Plastic Waste Generation*** **(per Capita)** and ***Recovery Rate of Plastic Packaging,*** to assess marine plastic pollution.

Target 14.2: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

UNSC proposed Indicator 14.2.1: Percentage of coastline with formulated and adopted ICM/MSP plans

Integrated coastal management (ICM), also referred to as integrated coastal zone management (ICZM), is the recommended approach for sustainable development and resource use of coastal areas.[9] In the open consulting forum, the proposed indicator has been criticized for not being properly defined and it is suggested that the indicator should be combined with the indicator on marine protected areas under 14.5 (IAEG-SDGs 2015). The UN International Strategy for Disaster Risk Reduction suggests using indicators on the number of deaths and missing people and on direct economic losses due to hazardous events. The UN Statistical Commission proposes to use the *Percentage of National EEZ Managed Using Ecosystem-Based Approaches*.

[8] We believe the *Gross P Balance* is not a useful indicator. It indicates double-digit positive figures only for the countries Cyprus, Croatia and Malta (max. value of 33 kg P/ha for Croatia in 2012) while all other countries have a close to zero or even negative P balance. In contrast, the gross N balance shows significant positive figures for all maritime EU countries except Latvia and Lithuania.

[9] http://www.unep.org/regionalseas/issues/management/mngt/default.asp

The EU Maritime Spatial Planning (MSP) directive came into force in September 2014 and EU countries are required to transpose the directive into national legislation with the aim that the implementation of MSP in their jurisdictional waters is achieved by 2021 (European Commission 2015). There are currently five initiatives listed for the implementation of MSP (Plan Bothnia, Preparatory Action on Maritime Spatial Planning in the Baltic Sea; BaltSeaPlan, Baltic Sea Region Programme project—Introducing Maritime Spatial Planning in the Baltic Sea; MASPNOSE, Preparatory Action on Maritime Spatial Planning in the North Sea; TPEA, Transboundary Planning in the European Atlantic—Project on Maritime Spatial Planning in the Atlantic including the Celtic Sea and Bay of Biscay; and ADRIPLAN, Adriatic Ionian maritime spatial planning).[10] Even though there will be some difference regarding the transposition of the directive into national legislation across countries, the overall variation in this goal would be rather low and for our illustrative investigation we do not consider an indicator on formulated and adopted ICM/MSP plans for our illustrative investigation of sustainable oceanic development in the EU. As discussed in Section 2.2, the decision to leave out an indicator has implications for the weighting scheme—giving more weight to the remaining indicators.

UNSC proposed Indicator 14.2.2: Ocean Health Index (OHI)

The OHI is a composite indicator which covers not only aspects related to target 14.2 but aims at measuring overall ocean health, including also the social and economic dimension. The proposed indicator is criticized in the open consulting forum for being difficult to interpret and not necessarily suitable for measuring environmental progress. The UN Statistical Commission does not consider this indicator any longer in its current proposal.

The OHI is calculated at the regional and global level by taking the weighted arithmetical average score of ten ocean-related societal goals (Halpern et al. 2012, 2015). The ten ocean-related societal goals of 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, 2015). Certain goals are aggregates of subgoals indicated by the terms in the parenthesis above. The goals and subgoals reflect not only 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 and is updated annually, currently providing information on ocean health until 2015 (www.oceanhealthindex.org). As mentioned before, it should only be used with caution to identify sustainable oceanic development as the applied aggregation method assumes unlimited substitution potential and, thus, satisfies only a concept of weak sustainability (Rickels et al. 2014, Visbeck et al. 2014).

The OHI aims at capturing all aspects of ocean health. Theoretically, the indicator is more appropriate for assessing overall progress against Goal 14 than providing information about a single target. Including the OHI as an individual indicator does also assign more weight to those parts of ocean health which are covered by other indicators for Goal 14.

Since Target 14.2 is frequently criticized as being too broad, vague and therefore meaningless for guiding sustainable development (Brandi 2015), we neglect both indicators (14.2.1 and 14.2.2) in our illustrative

[10] http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/#lang=EN;p=w;pos=11.754:54.605:4;bkgd=5:1;gra=;mode=1;theme=113:0.8:1:1;selection=16.413:41.78;

investigation of oceanic sustainable development in the EU. However, as several goals of the OHI cover aspects of ocean health which are not yet properly reflected in official statistics, we follow the recommendation of Brandi (2015) and use individual goals of the OHI as indicators for other targets (see below).

Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

UNSC proposed Indicator 14.3.1: Average marine acidity (pH) measured at agreed suite of representative sampling stations

Ocean acidification provides a serious risk for sustainable ocean development because in combination with increased heat stress lower pH values may pose a serious threat to the abundance, health, physiology, and biochemical properties of marine species (e.g., Doney et al. 2009, Visbeck et al. 2014). The proposed indicator is criticized in the open consulting forum for not measuring impacts of ocean acidification nor actions to minimize and address the impacts (IAEG-SDGs 2015). Furthermore, it is suggested that additional indicators are required to measure scientific cooperation. Accordingly, the UN Statistical Commission proposes to use *Carbonate Chemistry Parameters, Growth in Scientific Acidification Cooperation,* and *Loss of Marine Biodiversity Caused by Ocean Acidification* as indicators for ocean acidification.

State indicators on A*verage Marine Acidity* or on Carbonate Chemistry Parameters are in so far meaningful as they provide information about the progress of anthropogenic carbon accumulation in natural reservoirs like the indicator *Atmospheric Carbon Concentration* does. However, the level of marine acidity is determined by the rate of global carbon emissions (at least as long local alkalinity management measured are not considered). For that reason, we consider as a third indicator the ***Carbon Emissions (per Capita)*** as a pressure indicator which can actually be influenced by a country. Obviously, the information on carbon emissions are already part of indicators proposed for Goal 13 (*Take urgent action to combat climate change and its impacts*). Consequently, considering this information for Goal 14 again increases the overall weight attached to this indicator which needs to be accounted for in the overall assessment.

UNSC proposed Indicator 14.3.2: Coral coverage

Coral reefs are essential for marine ecosystems and livelihoods, in particular in the developing word (Hughes et al. 2012, Laurans et al. 2013, Bridge et al. 2013). Recent estimates indicate that more than 60 percent of global reefs are seriously threatened (e.g., Burke et al. 2011). The proposed indicator is criticized for being too narrow (ocean acidification affects also other marine resources), not sufficiently related to ocean acidification (coral degradation is also influenced other pressures) and being too region-specific (IAEG-SGDs 2015). As mentioned above, the UN Statistical Commission suggests using *Loss of Marine Biodiversity Caused by Ocean Acidification* as an indicator, replacing the indicator *Coral Coverage.*

Coral coverage does not seem to be an appropriate indicator because neither the health status of the coral reefs is reflected nor are main local pressures like coastal development or destructive fishing represented. While information related to unsustainable fishing are already captured by indicators proposed for other targets, information related to destructive fishing in combination with marine protected areas might serve as an better indicator to reduce local pressure on coral reefs.

For the case of the EU, this or other indicators related to local pressure on coral reef health are not considered because Europe simply does not have coral reefs. Nevertheless, ocean acidification might influence other natural products from the sea. Ocean acidification is included as *pressure* in the calculation of several goals of the OHI, affecting for example 3 of 6 subgroups in the goal *Natural Products*. For that reason we include the goal score ***Natural Product*** from the OHI as a fourth indicator, measuring impacts of ocean acidification.

Target 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

UNSC proposed Indicator 14.4.1: Fish species, threatened

A fish species could be threatened directly by fishing activity, either directly as a target species, being a by-catch species, or through destructive fishing practice. Furthermore, it could be threatened due to habitat alteration (for example by direct destruction or indirectly by climate change). Thus, the proposed indicator does not really capture pressures related to sustainable harvesting, but provides state information in relation to marine biodiversity.[11] The open consulting forum suggests to focus more on biologically sustainable levels and to consider additional information on by-catch of, for instance, sea turtles, sea mammals, or sea birds (IEAG-SDGs 2015). The UN Statistical Commission does not any longer include this indicator in its proposal. However, data on fish stocks within biologically sustainable limits (see below) is not expected to be available for all fish stocks in all regions. For that reason we include ***Number of Fish Species Threatened*** as our fifth indicator.

UNSC proposed Indicator 14.4.2: Proportion of fish stocks within biologically sustainable limits

The wealth contribution of fisheries goes beyond generating employment and cash income by also providing an essential nutrient source for people in particular developing countries (Dulvy and Allison 2009, Bell et al. 2009, Allison 2011, Hall et al. 2013). Regarding the different dimensions of sustainable development and acknowledging the roots of the SDGs in the MDGs the sustainable management of fish stocks appears to be an essential element for the SDG framework. Accordingly, the indicator receives a lot of attention in the open consulting forum (IAEG-SDGs 2015). For example, it is suggested that the proposed indicator could serve as a headline indicator for SDG 14. However, it is criticized that the term *biological sustainable limit* is not sufficient specific or well established (i.e., in comparison to maximum sustainable yield) and as alternative *proportion of population of fish stocks at or above biomass levels capable of producing maximum sustainable yield* is suggested. Furthermore, it is discussed whether additional indicators more related to pressure than to the state like fish mortality would be more appropriate. Such indicators could be supplemented with further indicators about fishing intensity, using for example fishing intensity maps (IAEG-SDGs 2015).

However, the proportion of fish stocks within biologically sustainable limits imposes several practical challenges for indicator design. Irrespective of the issue that it is difficult to agree on biological sustainable limits for all fish stocks, conceptual problems arise from the fact that countries obviously share fish stock. Furthermore, how would one assess a situation where all fish stocks are slightly below the biological sustainable limit in comparison to a situation where some fish stocks are above the limit but other fish stocks distinctly fall below it? For that reason we use as a sixth (state) indicator ***Biomass Reference Point BMSY*** provided by ICES (2015) in relation to MSY, weighted by the catch of a given country. It should be mentioned that such a reference point is not provided for every stock and where absent, we took the available reference points (e.g. biomass at precautionary level, BPA).[12]

[11] Similar to the Living Planet Index (Nicholson et al. 2012).
[12] The pressure indicator ***Fish Mortality*** will be used below for indicator 14.b.2 (Percent of Global Fish Catch from Sustainable Managed Fisheries).

Target 14.5: By 2020, conserve at least 10 percent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

UNSC proposed Indicator 14.5.1: Percentage area of each country's EEZ in MPA; Percentage area of ABNJ in MPA; Percentage area of global ocean under MPA

MPAs serve the purpose to improve stock resilience by creating areas where commercial fishing is prohibited and for example new generation of juveniles are allowed to replenish the resource (e.g., Sumaila et la. 2010). The open consulting forum notes that the proposed indicator requires either a better distinction or should be formulated in combination with indicator 14.2.1 (IAEG-SDGs 2015).

The socio-economic benefits of MPAs might not only be derived from the cumulative area of MPAs in the coastal and marine area. Edgar et al. (2014) show "that the conservation benefits of 87 MPAs investigated worldwide increase exponentially with the accumulation of five key features: no take, well enforced, old (>10 years), large (>100km^2), and isolated by deep water or sand (p. 216)." Nevertheless, in combination with other indicators related, for example, to governance, the proposed indicator appears to be meaningful for assessing conservation of coastal and marine areas. Both Brandi (2015) and Fulton et al. (2015) consider this target meaningful for sustainable development, in particular with respect to the conservation and protection of biodiversity. Furthermore, they suggest a target value of 30 percent. Protecting biodiversity in the European Union is governed by Natura 2000, an ecological network of protected areas.

The currently proposed indicator set actually includes three indicators, namely the area of MPAs in a country's EEZ, in ABNJ, and in global oceans. For our illustrative investigation of sustainable oceanic development and inter-country comparison in the EU, we choose ***Percentage Area of Each Country's EEZ in MPA*** as a seventh indicator.

UNSC proposed Indicator 14.5.2: Coverage of protected areas

The indicator might aim at particular areas for protection, for example catchment area of rivers, however this is not further specified. This is also criticized in the open consulting forum (IAEG-SDGs 2015). Furthermore, it is suggested to include further aspects measuring the quality of protecting (e.g., include information about management plans or distinguish between types of protected areas).

Natura 2000 distinguishes between special protected areas (SPA) and site of community interest (SCI), however, this distinction is not exclusive (i.e., SPAs and SCIs overlap) and is among other reasons a result of the different procurement procedure. Consequently, we do not distinguish further between the MPA areas in the countries of investigation, but regarding the importance of biodiversity for ocean health we include ***Biodiversity*** provided by the OHI as eighth indicator.

Target 14.6: By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation

UNSC proposed Indicator 14.6.1: Dollar value of negative fishery subsidies against 2015 baseline

Profit increasing subsidies (i.e., enhancing revenues and/or reducing fishing costs) result in increasing fishing effort and an overcapitalization of global fisheries and are considered therefore to be one of the main reasons for the ongoing depletion of world fish stocks (Hatcher and Robinson 1999; Munro and Sumaila 2002, Sumaila 2003). However, not all subsidies are considered to be *negative* in the sense that they contribute to the depletion of fish stocks, because certain subsidies can actually contribute to fishery resource conservation and management (e.g., Milazzo 1998). The open consulting forum emphasizes that it is difficult to define harmful subsidies and suggests that indicator formulation should be in line with WTO rules and should focus on capacity enhancing subsidies. The UN Statistical Commission does not consider this indicator any longer in its current proposal.

The distinction between positive (beneficial) and negative (capacity-enhancing) subsidies is not straightforward. Therefore, Sumaila et al. (2010) also considers ambiguous subsidies where the effect on fish stock conservation is not obvious. Such subsidies are, for example, controversial fisher assistance programs, vessel buyback programs or rural fisher community development programs which can result, depending on the specific situation and design, in either investment or disinvestment in the fishery resource (Sumaila et al. 2010).

The OECD Agricultural Statistics provide information on government financial transfers to the fishery sector. They provide information on direct payments, cost reducing transfers, general services, and cost recovery chargers. However, the data quality for the different categories is already poor on the EU level. We use ***Government Financial Transfers to Marine Capture Fisheries Relative to Gross Value Added*** as our ninth indicator, assessing fisheries subsidies.

UNSC proposed Indicator 14.6.2: Legal framework or tax/trade mechanisms prohibiting certain forms of fisheries subsidies

Like mentioned above, profit and capacity increasing fisheries subsidies are considered to be one of the main reasons for the ongoing depletion of world fish stocks. However, in the open consulting forum the proposed indicator is not considered to useful because it is difficult to monitor and countries are expected to establish substitute subsidies (IAEG-SDGs 2015). The UN Statistical Commission proposes to use *Progress by Countries in the Implementation of International Instruments Aiming to Combat IUU Fishing* as Indicator.

Nevertheless, the design of resource-specific institutions and regulation is considered to be an essential element for managing free-access marine resources (e.g., Ostrom 1990). To measure how well fishery regulations are enforced in the EU, we use ***Landings Exceeding Total Allowed Catch (in metric tons)*** as our tenth indicator.

Target 14.7: By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

UNSC proposed Indicator 14.7.1: Fisheries as a % of GDP

Estimates for the value provided by the ocean-based economy range from 0 to 5 percent of GDP for developed countries. In several developing countries, however, this share can increase to approximately 10 percent (Kildow and McIlgorm 2010, Scholtens and Badjeck 2010, Allison 2011). The proposed indicator has received much attention in the open consulting forum. It is criticized that the indicator does not account for sustainability because increasing shares of GDP could be accompanied with less well maintained fish stocks; furthermore, it could also be a sign for fewer development in other sectors (IEAG-SDGs 2015). Consequently, it is suggested to relate the information to some kind of sustainability measure (e.g., revenues generated from fish stocks within maximum sustainable yield) (IEAG-SDGs 2015). Furthermore, it is discussed to consider not only revenues from fisheries, but also from aquaculture and tourism. The UN Statistical Commission proposed to use *Revenues and ecosystem services derived from sustainable fisheries, aquaculture, tourism and other coastal and marine resources uses* as indicator.

The discussion shows very well that assessing sustainable development can benefit from composite indicators. Sustainable development also involves the economic dimension. Improving several other indicators could a potentially result in negative effect on the economic benefits (e.g., from increasing the size of MPAs, stronger regulation of fisheries, reduction of subsidies). For that reason improvements of those indicators should be assessed against changes in this indicator. In fact, the suggested indicators by the UN Statistical Commission are composite indicators.

Despite the particular focus on Small Island developing States and least developed countries, we also include information about this dimension in our illustrative investigation of sustainable oceanic development in the EU and use ***Coastal Livelihoods & Economics*** from the OHI as the eleventh indicator.

UNSC proposed Indicator 14.7.2: Level of revenue generated from sustainable use of marine resources

As discussed for the previous indicator, comprehensive assessment of ocean sustainability requires including not only indicators on the ecological dimension but also indicators to measure the socio-economic benefits obtained from a sustainable use of the ocean. The proposed indicator has been criticized for being too unspecific in the open consulting forum (IAEG-SDGs 2015). The UN Statistical Commission proposed to use *Productivity of aquaculture in utilizing natural resources (land, water and wild stock)*.

While for small developing island states measures on the sustainable use of aquaculture appear to be suitable, we focus on another dimension of marine resources for the EU, namely sustainable tourism and recreation. Accordingly, we use ***Tourism & Recreation*** from the OHI as our twelfth indicator.

Target 14.a: Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

UNSC proposed Indicator 14.a.1: Number of researchers working in this area

UNSC proposed Indicator 14.a.2: Budget allocated to research in the field of marine technology

Increasing scientific knowledge of ocean health and incorporating scientific insights into policy design is an essential element of sustainable oceanic development (Brandi 2015). However, despite being essential, the formulation of the target is rather broad and does not allow deriving specific activities (Fulton et al. 2014). The proposed indicator is criticized for being too specific and only applicable for a certain set of countries (IAEG-SDGs 2015). Furthermore, it is criticized that the number of research indicates is only a poor proxy for the volume of marine knowledge and the transfer of knowledge and technology (IAEG-SDGs 2015). The UN Statistical Commission proposed to use *% of GDP invested in ocean research*, *Growth in ocean science capacity, technology and knowledge, as well as cooperation between countries and regions,* and *Budget allocation to research in the field of sustainable marine technology as a percentage of all research in field of marine technology* as alternative indicators.

The target or potentially underlying indicators are already implicitly included in other targets as for example economic development in Small Island States/Least Developing Countries (Target 14.7) requires technological transfer. The two proposed indicators, *number of researchers working in this area* and *budget* *allocated to research in the field of marine technology* are only partly suited to measure progress in this dimension of sustainable oceanic development. First, the other non-oceanic SDGs certainly also requires improved scientific capacities for development. Consequently, indicators related to scientific capacities should probably be included in SDG *17: Strengthen the means of implementation and revitalize the global partnership for sustainable development* where it is required that scientific capacities should grow in a balanced way. Second, neither the number of researchers nor the budget allocated indicates whether meaningful and sustainable research progress is achieved.

To include information about whether scientific capacities, insights, and advice are part of policy design, we include two alternative indicators: ***Number of Marine Monitoring Stations relative to EEZ*** (13^{th} indicator) and ***TAC Exceedance of Scientific Advise*** **(in metric tons)** (14^{th} indicator). The first serves as a proxy for scientific capacities to monitor the status of marine waters, the second serves as a proxy in how scientific findings and recommendations are considered in policy making.

Target 14.b: Provide access for small-scale artisanal fishers to marine resources and markets

UNSC proposed Indicator 14.b.1: By 2030, X% of small scale fisheries certified as sustainable; Y% increase in market access for small scale fisheries

UNSC proposed Indicator 14.b.2: By 2030, increase by X% the proportion of global fish catch from sustainably managed small scale fisheries

In addition to economic development, artisanal fishing provides services like maintaining a minimum standard of living and providing some kind of safety-net and vulnerability reduction mechanism (Béné et al. 2010). The proposed indicator receives much attention in the open consulting forum, in particular with respect to the definition of small-scale fisheries. It is suggested to provide further information (at the specific regional level) on which activities and operators are to be considered as small-scale and vulnerable (IEAG-SDGs 2015). It is also suggested to related capture made by small-scale fisheries to the total catch and to include information on whether fishers are part of a traceability plan (IEAG-SDGs 2015). Furthermore, it is discussed in how far indicators on loans for sustainable fisheries or private sector investment in sustainable fisheries could provide information for a meaningful indicator (IEAG-SDGs 2015). The UN Statistical Commission suggested *Progress by countries in adopting and implementing a legal/regulatory/policy/institutional framework which recognizes and protects access rights for small-scale fisheries* and *Percentage of catches that are subject to a catch documentation scheme or similar traceability system as a percentage of the total catches that are less than x tons and traded in major markets* as revised indicators.

136 of 144 maritime countries engage in small-scale or artisanal fishing, employing more than 90 percent of the 35 million fishers worldwide and proving about 90 million additional jobs in associated sectors like fish processing, distribution and marketing (Halpern et al. 2012, Teh and Sumaila 2013). However, the global estimates do not capture the seasonal and transient nature of the employment in small-scale fisheries (The and Sumalia 2013). Barnes-Mauthe et al. (2013) show for example that in certain regions of Madagascar about 87 percent of the adult population work full- or part time in the small-scale fishery sector. Such field studies highlight the importance of artisanal fishing for local economics by providing cash income and absorbing rural surplus labor, however, the growth-linkages and poverty prevention effects have neither been properly quantified nor considered in in development policies (Bene et al. 2010, Allison 2011). Acknowledging the poverty prevention and therefore welfare effect would suggest putting more weight to inclusive management systems to support people's occupational and temporal mobility and to find a better balance with wealth-based approaches which seek to increase the rents from fishing to stipulate poverty reduction but also exclude people form the fishery (Bene et al. 2010).

Clearly, the indicator aims in particular at Small Island States and (Least) Developing Countries and is of less relevance for the EU marine countries. Nevertheless, for our illustrative investigation of sustainable oceanic development we include ***Artisanal Fishing Opportunities*** from the OHI as the 15th indicator in our investigation. In addition to acknowledging the role of small-scale fisheries for development and poverty prevention, the target also aims at increasing the share of sustainable fisheries. However, sustainable fishing practices and management should not be restricted to small-scale fisheries. For that reason, we include ***Fishing Mortality (FMSY)***, measured in relation to the fishing mortality rate which generates maximum sustainable yield, for all commercial fish stocks (ICES 2015).[13]

Target 14.c: Ensure the full implementation of international law, as reflected in the United Nations Convention on the Law of the Sea for States parties thereto, including, where applicable, existing regional and international regimes for the conservation and sustainable use of oceans and their resources by their parties

UNSC proposed Indicator 14.c.1: Adoption of a legal framework and number of associated court cases

UNSC proposed Indicator 14.c.2: Number of countries implementing either legally or programmatically the provisions set out in regional seas protocols

The United Nations Convention on the Law of the Sea (UNCLOS) does not cover several areas related to ocean health like overfishing, climate change, or activities in polar waters—nevertheless, taking into account that it has been negotiated such a long time ago it deserves credit for its comprehensiveness and integrative character (Visbeck et al. 2014b). The proposed indicators have not yet receive much attention in the open consulting forum (IAEG-SDGs 2015). The UN Statistical Commission proposes *Number of countries implementing either legally or programmatically the provisions set out in Regional Seas protocols and ratification and implementation of the ILO Maritime and Fisheries Conventions*, *Progress by countries in [level/degree of] implementation of provisions of the Code of Conduct for Responsible Fisheries (CCRF) and associated guidelines and plans, as reported in the biannual CCRF questionnaire surveys,* and *Number of countries ratifying/implementing IMO environmental conventions, e.g., MARPOL, the London Convention/Protocol, and the Ballast Water Management Convention* as revised indicators.

As already discussed in the context of MPAs, measuring actions like designating protected areas or signing regional sea protocols are by themselves not necessarily provide good information on successful ocean governance as further aspect of for example enforcement have also to be monitored (e.g., Edgar et al. 2014). Nevertheless, the act of signing regional and international sea protocols usually implies that some capacities and legal expertise is available regarding the aspects covered. For our investigation of sustainable oceanic development in the EU we do not consider the participation in regional sea protocols, because HELCOM, OSPAR, the Barcelona and Bucharest Convention have full coverage of the relevant EU marine countries considered. We choose instead the **Participation Rate in International Sea Protocols** as the 17th indicator for our illustrative assessment of sustainable oceanic development in the EU. The sea protocols considered are the marine environmental agreements include the Convention of Biological Diversity, the Convention on the International Trade in Endangered Species of Wild Flora and Fauna, the Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the United Nations Convention on the Law of the Sea, the Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter, the International Convention for the Prevention of Pollution from Ships, the International Convention for the Regulation of Whaling, and the Convention on Fishing and Conservation of the Living Resources of the High Seas.

[13] Note that, in contrast to the state indicator ***Biomass Reference Point BMSY*** (sixth indicator, used for target 14.4), this indicator is a pressure indicator.

3.2 A Composite Index to Assess Sustainable Oceanic Development

Given a broad set of indicators, I_i, the aggregation into a composite indicator (CI) is complicated by the different measurement units of the variables which make them non-comparable (e.g., *Gross Nutrient Balance* in kg/ha versus *CO_2 Emissions* in kg per capita). Given that all selected indicators are ratio-scale measurable, a meaningful aggregation could 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 based on the composite indicator is not influenced by the measurement units in which the indicators are expressed (e.g., Ebert und Welsch 2004, Böhringer and Patrick 2007). However, using a geometric mean for ratio-scale non-comparable indicators allows only for an ordinal and not a cardinal comparison of the underlying states and furthermore precludes investigation of different levels of substitution possibilities.

Consequently, the indicators need to be 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 transformed indicators that range from 0 to 100. Assuming that indicators for the sub-goals are ratio-scale measurable and fully comparable, meaningful aggregation into a CI is obtained by applying generalized means (Blackorby and Donaldson, 1982):

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

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 CI depending on σ. These are denoted by $CI(\sigma)$ for the case of a given set of indicators and weights. A concept of strong sustainability permits no substitution possibilities among the different indicators ($\sigma = 0$), resulting in a measure of sustainable development governed by indicator that performs worst ($CI(0) = min\{I_i\}$). The other extreme, the case of perfect substitution possibilities ($\sigma \to \infty$) results in the arithmetic mean ($CI(\infty) = \sum_{i=1}^{N} \alpha_i I_i$). In this extreme case, the distribution of scores over the different indicators only has any bearing on the value of the CI to the extent that the weights may differ.

For our illustrative investigation of sustainable oceanic development in the EU, we use indicator-specific scaling factors to obtain indicators ranging between 0 and 100. Table A2 in the Appendix shows for all selected indicators the data source, the time period, and the applied scaling factor. Following Dovern et al. (2014), we apply a nested index, implying that we aggregate first those indicators with better substitution possibilities (regarding the reflected dimension). On this first level, we aggregate, for instance, the two indicators 2.a and 2.b which both measure plastic pollution. On the second level, we aggregate the indicators associated with each target. (Note that the CI for plastic pollution determined at the first stage is treated as one indicator at this level.) On the third level, we aggregate the CIs corresponding to the individual targets to obtain the overall CI measuring the state of oceanic development in the EU. Figure 1 shows an excerpt of the nesting structure of our assessment. We consider equal weights (α_i) for all indicators at each of the stages. Since a sufficient data history is available for only about half of the selected indicators, we restrict our investigation to the current state of oceanic sustainable development in the EU.

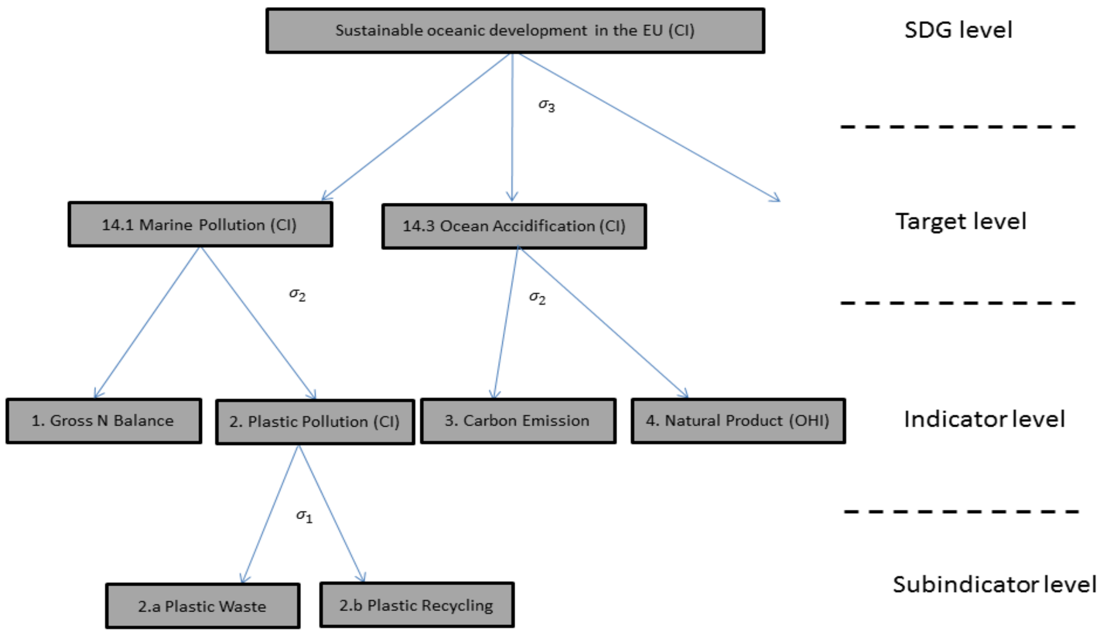

Figure 1: Nesting structure for assessment of sustainable oceanic development in the EU

3.3 Results

The broad set of selected indicators allows identifying the strengths and weaknesses of EU coastal states regarding their oceanic health. An explicit assessment would require a detailed investigation and comparison of each EU coastal state for each indicator, similar to, for instance, the indicator report for the National Sustainable Strategy of Germany (Statistisches Bundesamt 2012). Such a detailed investigation is beyond the scope of this paper and we turn directly to the discussion of the CIs. For that purpose, we first show the normalized scores for the indicator level in Figure 2. The figure shows the average of all EU country scores together with the scores for Denmark, Germany, and France. The results indicate, for instance, that the EU in total has large potential for increasing its efforts in assigning MPAs and that Germany has relatively strong potential for making marine tourism more sustainable.

While the analysis of individual indicators is important for designing EU marine policy, it does not allow for a straightforward identification of countries that are successful overall in terms of their marine policy. Neither does it allow identifying which countries actually achieved sustainable oceanic development over time. (Except for the rare cases that one country has higher scores for each indicator than another country or that a country improves its score for every indicator.)

The aggregation requires a choice about the substitution potential between indicators. While on the indicator level an increase in one subindicator can rather well be compensated by a decrease in another subindicator, such high substitutability is questionable at the target level. For example, an increase in plastic pollution might not be well compensated by an equal decrease in nutrient pollution. Accordingly, we show results for different concepts of sustainability, i.e. different levels of substitution potential at this level. The left panel of Figure 3 shows the scores for all targets with $\sigma_2 = 10$ (weak sustainability) for the EU average together with those for Portugal, Sweden, and Italy; the right panel shows the corresponding results for $\sigma_2 = 0.5$ (strong sustainability). The right panel, thus, helps to identify those targets for which a rather unbalanced performance is achieved. The performance of Sweden or Portugal in terms of acidification, for instance, reveals that the performance across indicators seems to be rather unbalanced because the target score is much higher under the assumption of weak sustainability than under the assumption of strong sustainability.

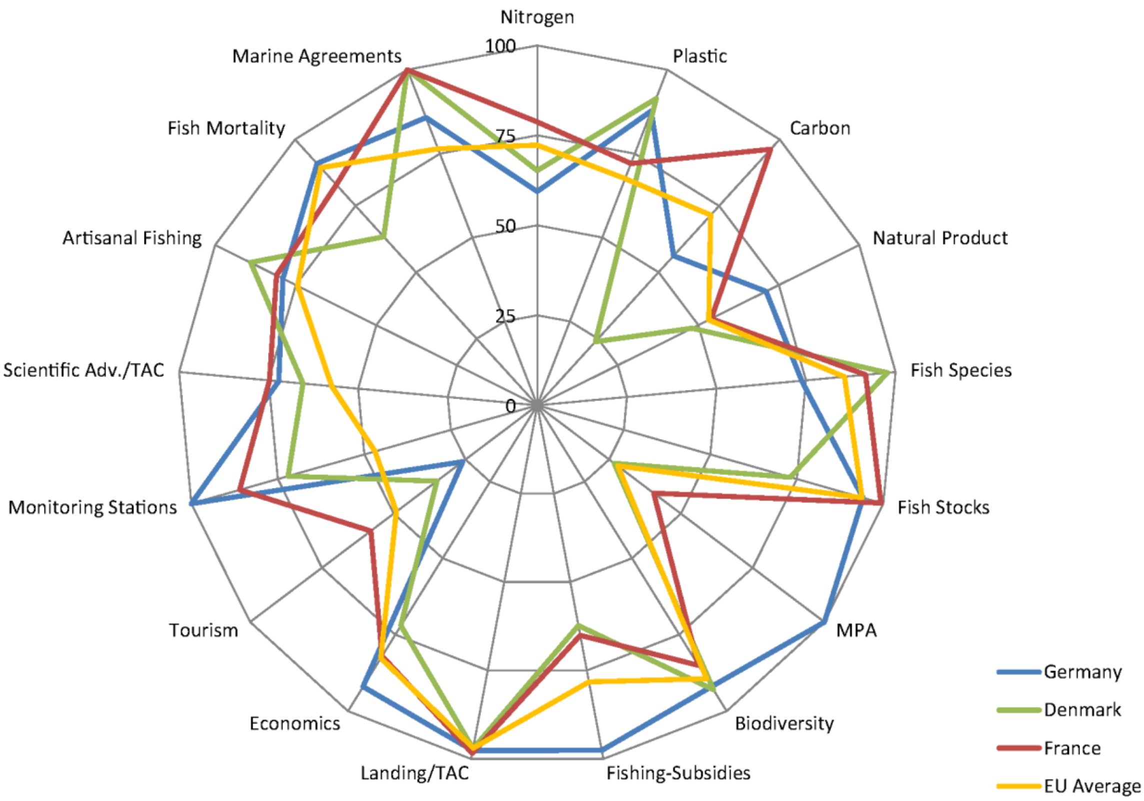

Figure 2: *SDG 14 Indicator Score for selected EU coastal states.*

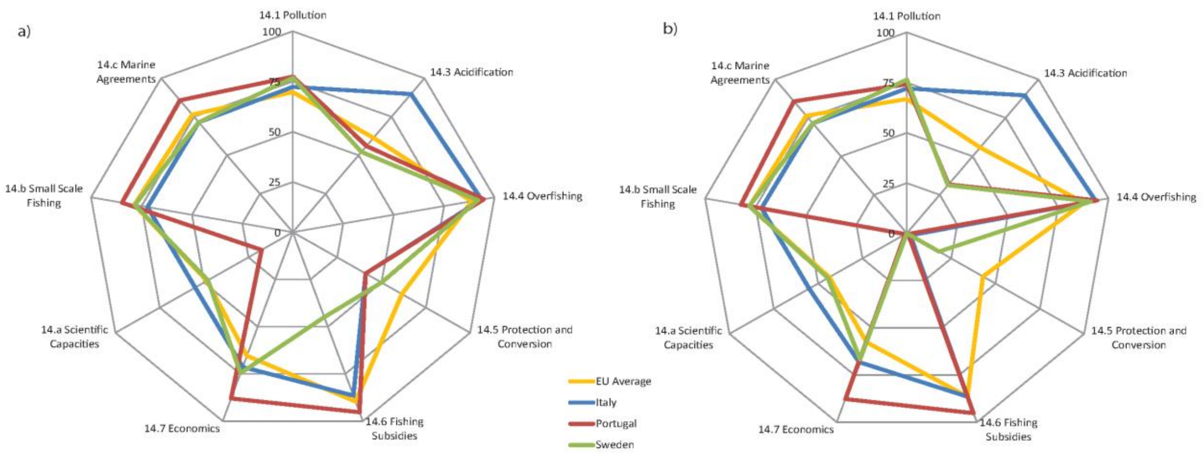

Figure 3: *SDG Goal 14 Target Score for selected EU coastal states. Left panel a) for a concept of weak sustainability (*$\sigma_2 = 10$*) and right panel b) for a concept of strong sustainability (*$\sigma_2 = 0.5$*).*

Obviously, one needs to keep in mind the sensitivity of the indicators to the transformation. This can be illustrated by applying monotonic transformation to the indicators which leave the ranking of the individual indicator unchanged. For example, transforming the original indicators, I_i, according to $I_i^* = I_i \times 100 \times (I_i/100)^\beta$ with $\beta > 0$ yields an transformed indicator that implies the same ranking and ranges also from 0 to 100. Yet, the relative performance between the goals can be very different depending on whether the original indicators or the transformed ones are used. Figure 4 illustrates this for the EU average of the indicators analyzed above. The yellow curve shows the performance based on the original indicators as shown above. Yet, there is no unique scientific reason why this is the one and only way of measurement. The red curve is obtained using the same data when, in addition, indicators for *Overfishing* and *Fishing Subsidies* are transformed with the above increasing function, specifying $\beta = 3$, while the indicators for *Scientific Capacities* and *Acidification* are transformed specifying $\beta = 0.5$. The resulting relative performance is much more equalized across goals. The blue curve is obtained using similar transformations, but with the specifications for the parameter β reversed, such that the relative performance looks very unequal now.

Accordingly, the transformation of the original indicators requires as much attention and transparency as the selection of the indicators. By defining target values, the current outline of the SDG framework, however, already specifies for several indicators the potential scaling factor. However, even after agreeing on transformations and aggregation at the lowest level, the amount of inflation displayed in Figures 3 and 4 is still too large to easily deduce an overall assessment for comparing countries or tracking the development of one country over time. To condense the information a further aggregation step can be done to obtain an overall CI.

For our illustrative assessment of sustainable oceanic development in the EU, we proceed by assuming sufficient substitution possibilities between the indicators assigned to targets ($\sigma_2 = 10$). At the same time, we assume that the ocean health at the aggregate level is complex and requires a concept of strong sustainability. This means that the aggregation of individual targets into an overall score (SDG level) requires a substitution elasticity below 1. Instead of selecting a specific value for the substitution elasticity, we carry out a Monte Carlo analysis (N=10,000), assuming that σ_3 is uniformly distributed between 0 and 1. Table 1 shows the results for all EU states and their averages. The table includes information about the average score, its standard deviation (across the Monte Carlo iterations), the mean and standard deviation of the implied rank, and, for comparison, the scores and ranks obtained under the assumption of perfect substitution possibilities.

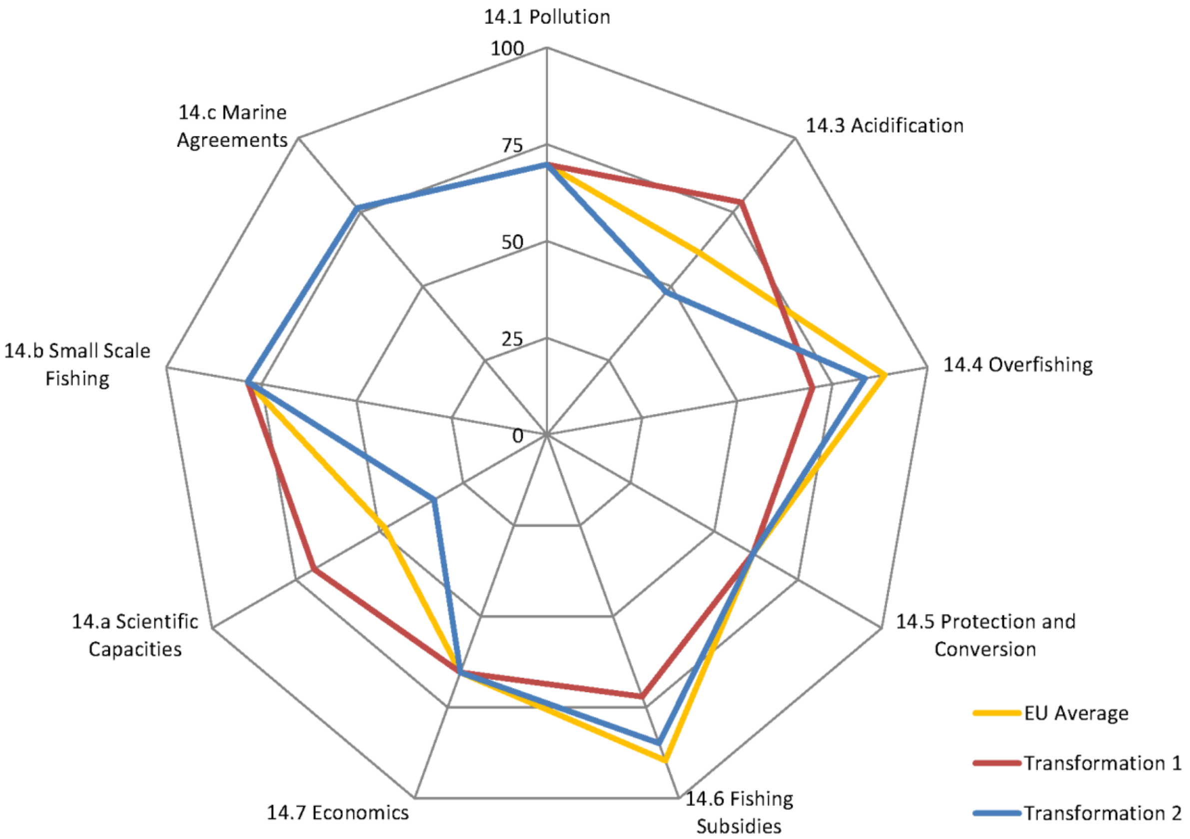

Figure 4: *SDG 14 EU-average target score with* $\sigma_2 = 10$ *with different monotonic transformation of the indicators. The yellow line shows the scores with the original transformation (EU Average), the red line shows the scores with an equalizing transformation (Overfishing and Fishing Subsidies are transformed using* $\beta = 3$, *Scientific Capacities and Acidification are transformed using* $\beta = 0.5$, *for all other indicators* $\beta = 1$ *(Transformation 1). The blue line is obtained with the specification for the parameter* β *reversed (Transformation 2)* .

The score obtained under perfect substitution possibilities (i.e. the arithmetic mean) is by construction higher than the score obtained under limited substitution possibilities, except for the unlikely case that a coastal state has identical scores for each target. However, the ranking information are comparable, showing, for example, that countries with unbalanced scores across targets like Portugal or Ireland perform poorer in an assessment with limited substitution possibilities. In contrast, countries with a rather balanced performance rank considerably better in an assessment with limited substitution possibilities.

Table 1: Assessment of sustainable development in the EU

	$\sigma \sim U(0,1)$				$\sigma \to \infty$	
Countries	**Ave_Score**	**Std.**	**Ave_Rank**	**Std.**	**Score**	**Rank**
Germany	75.99	4.61	1.26	0.44	81.01	1
France	75.59	2.70	1.74	0.44	80.20	2
Belgium	71.19	4.54	3.63	0.48	77.31	3
Lithuania	70.36	6.94	3.68	1.12	74.81	6
Slovenia	67.10	3.21	6.06	1.74	70.89	12
Italy	64.54	7.55	6.88	1.54	72.56	9
Ireland	64.19	7.72	7.19	1.93	75.46	4
Finland	65.56	3.98	7.86	1.91	73.99	7
Spain	62.26	9.45	10.18	2.44	75.31	5
United Kingdom	62.17	7.93	11.12	0.95	72.88	8
Latvia	60.42	11.65	11.16	3.81	72.35	10
Netherlands	62.58	4.49	11.16	2.51	69.65	14
Romania	61.68	7.31	12.00	0.27	69.38	15
Poland	61.12	5.24	12.61	2.14	68.08	16
Sweden	58.67	4.17	14.60	2.57	65.32	20
Denmark	58.67	7.68	14.87	0.34	70.63	13
Estonia	49.37	8.45	17.81	0.97	61.64	21
Malta	46.95	11.82	18.05	0.21	65.77	18
Portugal	45.82	14.28	18.14	0.98	71.16	11
Croatia	41.76	13.52	20.00	0.00	65.72	19
Cyprus	31.19	10.52	21.58	0.88	58.93	23
Bulgaria	27.54	14.58	21.90	0.30	60.36	22
Greece	24.28	16.78	22.53	0.82	67.39	17
EU Average	*65.79*	*4.67*			*71.08*	

6 Conclusion and Recommendation

The 2030 Agenda for Sustainable Development that includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets could be a step forward in achieving efficient governance and policies for global sustainable development. For living up to their expectations, the SDGs have to become part of international and national policies, with proper coordination, monitoring, and assessment of sustainable development policies.

While the adoption of the Agenda 2030 by the General Assembly in September 2015 was an important signal from the world leaders to strive for a sustainable future, the actual success of the agenda will depend on the progress made in the next months and years towards a mechanism for monitoring and financing. An essential element will be the global indicator framework to monitor and assess progress over and against both the overall goals and the specific targets and to guide policy towards sustainable solutions. Unlike previous top-down approaches, the development of the overall agenda and also the indicator framework has been and is still organized to include the opinions and expertise from different experts, partners, and stakeholders. Consequently, the indicators framework has good prospects to achieve a reasonable compromise between the diverging goals of statistical measurability, scientific consistency, and political relevance.

So far, the process has resulted in large number of proposed indicators (about 300). While such a high number is considered to be necessary to fulfill the criteria of being useful in a management context and for the purpose of (statistical) capacity building (UN 2015), the high number of indicators amplifies evaluating the overall success in achieving sustainable development. Certainly, it needs to be acknowledged that currently discussed indicators are only preliminary proposals and many changes and adjustments will be incorporated before the overall indicator framework will be adopted in 2016. The participants of the 46th session of the UN Statistical Commission themselves have evaluated only 16 percent of the preliminary indicators as being feasible, suitable and very relevant. 31 percent have been evaluated to as being difficult to apply even with strong effort while also being only partly suitable and only somehow relevant. Consequently, the discussion on the indicators in the open consulting framework revealed and addressed already many potential issues and problems and has resulted in a revised proposal by the UN Statistical Commission.

However, in the debate over the current indicator framework, little attention seems to be devoted to conceptual issues. In particular, this holds true for the question of how sustainable development is supposed to be assessed overall. It is surprising that composite indices are opposed and, instead, the use of a large number of stand-alone indicators is favored as the backbone of the operationalization of the SDGs based on 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. Pintér et al. (2005) and Kopfmüller et al. (2012) argue that a small set of indicators has greater relevance for decision-makers. However, facing this large set of goals (and even larger set of targets), it seems to be very unrealistic to end up with a number of (headline) indicators which can still be overseen by decision-makers. Clearly, the statistical requirement of selecting indicators which are (simple) measurable, robust, and comparable is a strong argument of avoiding more complicated composite indicators.

However, using composite indicators as complements to the single indicators could support the overall assessment process without necessitating any significant changes to the currently proposed indicator base. While the individual indicators remain the backbone of the indicator framework, serving the purpose for detailed assessment of specific policy measures, the composite indicators, allow for an explicit assessment of trade-offs between policies. 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 indicator sets (given no policy exist that improves all indicators). The current outline of the indicator framework for the SDGs (i.e., an indicator set without explicit treatment of trade-offs) could be interpreted as an assessment approach following a concept of strong sustainability, according to which sustainable development requires that all indicators have to be at least maintained at the current level. 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 is technically not achieved. It should also be noted 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 a very different concept than optimality.

Our illustrative assessment of sustainable oceanic development of EU coastal states has demonstrated that the inclusion of composite indicators provides important additional information. The individual indicators are important to compare and assess the influence of marine policies across states and time, however, they do not allow for a straightforward identification in how far an overall balanced marine policy is achieved. For that reason, the additional inclusion of composite indicators could help to detect the arbitrary application of management measures focusing only on less critical or easy to achieve areas (indicators). The SDG framework allows not only for aggregation across the different goals, but also across the different dimensions of sustainable development (i.e., by aggregating the indicators corresponding to the social, the indicators corresponding to ecological, and the indicators corresponding to the economic dimension).

Implicitly, the suggestions in the open consulting framework already call for the inclusion of composite indicators. This is evident, for instance, in the discussion on Indicator 14.7.1 (*Fisheries as Percentage of GDP)*. Here, the comments reveal that this indicator should be combined with further information on the sustainability of the revenues in order to be meaningful for SDG 14, implying the use of a composite indicator. However, we would argue that because of statistical requirements, the base level indicators should be as easy as possible and that such assessment of trade-offs should be based on additional composite indicators.

Obviously, the application of composite indicators requires the decision about weighting and scaling schemes, and the specification of the substitution elasticity. However, these decisions and specifications are not qualitatively different from the overall process of selecting and dumping indicators in the alternative approach because these tasks implicitly also involve a weighting decision. Scaling schemes are already implicitly given once target values are agreed on for specific indicators. Moreover, the specification of the elasticity of substitution allows for a straightforward sensitivity analysis, providing additional information for sustainable development assessment. Our illustrative investigation of the sustainable oceanic development of EU coastal states highlights how much a comprehensive assessment can benefit from the additional inclusion of composite indicators.

References

Allison, E. H. 2011. Aquaculture, fisheries, poverty and food security, World Fish Center Working Paper 2011-65.

Armington, P. S. 1969. A theory of demand for products distinguished by place of production, IMF Staff Papers 16(1): 159–78.

Arrow, K. J., H. B. Chenery, B. S. Minhas, and R. M. Solow 1961. Capital-labor substitution and economic efficiency. *Review of Economics and Statistics* 43: 225-50.

Arrow, K. J., P. Dasgupta, and K. G. Mäler 2003. Evaluating projects and assessing sustainable development in imperfect economics. *Environmental and Resource Economics* 26: 647–85.

Barnes-Mauthe, M., K. L. L. Oleson, and B. Zafindrasilivonona 2013. The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. *Fisheries Research* 147: 175–85

Bateman I. J., G. M. Mace, C. Fezzi, G. Atkinson, and K. Turner 2011. Economic analysis for ecosystem service assessments. *Environmental Resource Economics* 48: 177–218.

Baumgärtner S. and M. F. Quaas 2007. Ecological-economic viability as a criterion of strong sustainability under uncertainty. *Ecological Economics* 68: 2008-2020.

Baumgärtner S., M. A. Drupp, and M. F. Quaas 2015. Subsistence, substitutability and sustainability in consumption. *Environmental and Resource Economics*, forthcoming. doi 10.1007/s10640-015-9976-z.

Béné, C., B. Hersoug, and E. H. Allison 2010. Not by rent alone: analysing the pro-poor functions of small-scale fisheries in developing countries. *Development Policy Review* 28(3): 325–58.

Blackorby, C. and D. Donaldson 1982. Ratio-scale and translation-scale full interpersonal comparability without domain restrictions: admissible social-evaluation functions. *International Economic Review* 23: 249-268.

Böhringer, C. and E. P. J. Patrick 2007. Measuring the immeasurable — A survey of sustainability indices. *Ecological Economics* 63(1): 1–8.

Brandi, C. 2015. Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. In The Sustainable Development Goals of the Post-2015 Agenda—Comments on the OWG and SDSN Proposals, ed. M. Loewe and N. Rippin (Deutsches Institut für Entwicklungspolitik gGmbH), 71–76. Bonn.

Bridge, T. C. L., T. P. Hughes, P. Terry, J. M. Guinotte, and P. Bongaerts 2013. Call to protect all coral reefs. *Nature Climate Change* 3(6): 528–530.

Brundtland, G. H., M. Khalid, S. Agnelli, S. A. al-Athel, B. Chidzero, L. M. Fadika, et al. 1987. Our common future. World Commission on Environment and Development. United Nations.

Burke, L., K. Reytar, M. Spalding, A. Perry 2011. Reefs at risk, revisited. World Resource Institute, Washington, DC.

Ciriacy-Wantrup, S. V. 1952. Resource conservation: Economics and policies. University of California Press, Berkeley.

Daly, H. and J. Cobb 1989. For the common good. Beacon Press, Boston.

Dasgupta, P. 2009. The welfare economic theory of green national accounts. *Environmental and Resource Economics* 42: 3–38.

De Lara, M. and L. Doyen 2008. Sustainable management of natural resources. Mathematical models and methods. Springer, Berlin.

Doney, S. C., V. J. Fabry, R. A. Feely, and J. A. Kleypas 2009. Ocean acidification, the other CO_2 problem. *Annual Review of Marine Science* 1: 169-192.

Dovern J, W. Rickels, and M. F. Quaas 2014. A comprehensive wealth index for cities in Germany. *Ecological Indicators* 41: 79-86.

Dulvy, N. and E. Allison 2009. A place at the table? *Nature Reports Climate Change* 0906: 68–70. http://dx.doi.org/10.1038/climate.2009.52.

Ebert, U. and H. Welsch 2004. Meaningful environmental indices: a social choice approach. *Journal of Environmental Economics and Management* 47: 270-283

Edgar, G. J., R. D. Stuart-Smith, T. J. Willis, S. Kininmonth, S. C. Baker, S. Banks, et al. 2014. Global conservation outcomes depend on marine protected areas with five key features. *Nature* 506(7487): 216–220.

EU (European Commission) 2015. The maritime spatial planning directive. doi 10.2771/693891, ISBN 978-92-79-45029-7.

Fenichel, E. P. and J. K. Abbott 2014. Natural capital: from metaphor to measurement. *Journal of the Association of Environmental and Resource Economists* 1(1/2): 1–27.

Fulton, B., M. Visbeck, K. Houghton 2015. Goal 14: Conserve and sustainable use the oceans, seas, and marine resources for sustainable development, in ICSU und ISSU: Review of targets for the sustainable development goals: the science perspective. Paris, pp. 67–70.

Gerlagh, R. and B. van der Zwaan 2002. Long-term substitutability between environmental and man-made goods. *Journal of Environmental Economics and Management* 44: 329-345.

Hall, S. J., R. Hilborn, N. L. Andrew, and E. H. Allison 2013. Innovations in capture fisheries are an imperative for nutrition security in the developing world. *Proceedings of the National Academy of Sciences* 110(21): 8393–8398.

Halpern, B. S., C. Longo, D. Hardy, K.L. McLeod, J.F. Samhouri et al. 2012. An index to assess the health and benefits of the global ocean. *Nature* 488(11397): 615–620.

Halpern, B. S., C. Longo, J. S. S. Lowndes, B. D. Best, M. Frazier, S. K. Katona, et al. 2015. Patterns and emerging trends in global ocean health. *PLoS ONE* 10(3): e0117863. doi:10.1371/journal.pone.0117863.

Hamilton, K. 1994. Green adjustment to GDP. *Resources Policy* 20: 155–168.

Hartwick, J. 1990. Natural resources, national accounts, and economic depreciation. *Journal of Public Economics* 43: 291–304.

Hatcher, A. and K. Robinson 1999. Overcapacity, overcapitalization and subsidies in European fisheries. In Proceedings of the first workshop held in Portsmouth, UK, October 28–30, 1998. Portsmouth: CEMARE, University of Portsmouth.

Heal, G. 2009. The economics of climate change: A post-Stern perspective. *Climatic Change* 96: 275-297.

Hughes, S., A. Yau, L. Max, N. Petrovic, F. Davenport, M. Marshall, T. R. McClanahan, E. H. Allison, and J. E. Cinner 2012. A framework to assess national level vulnerability from the perspective of food security: The case of coral reef fisheries. *Environmental Science & Policy* 23: 95-108.

IAEG-SDG (Inter-agency and Expert Group on Sustainable Development Goal Indicators) 2015. Open consultation for members and observers. http://unstats.un.org/sdgs/files/open-consultation-iaeg/Open_Consultation_Compilation-Members_and_Observers-20150915.pdf

ICES (International Council for the Exploration of the Seas) 2015. Advice. http://www.ices.dk/publications/library/Pages/default.aspx.

IUCN (International Union for Conservation of Nature) 2015. The IUCN red list of threatened species. Version 2015-3. http://www.iucnredlist.org. Downloaded on 9 September 2015.

Jambeck, J. R., R. Geyer, C. Wilcox, T. R. Siegler, M. Perryman, A. Andrady, et al. 2015. Marine pollution. Plastic waste inputs from land into the ocean. *Science* 347(6223): 768–771.

Kildow, J. T. and A. McIlgorm 2010. The importance of estimating the contribution of the oceans to national economies. *Marine Policy* 34: 367-374.

Kopfmüller, J., J. R Barton, and A. Salas 2012. How sustainable is Santiago? In: Risk habitat megacity, ed. D. Heinrichs, K. Krellenberg, B. Hansjürgens, and F. Martinnez, pp. 305–26. Heidelberg, Dordrecht, London, New York: Springer.

Laurans, Y., et al. 2013. Economic valuation of ecosystem services from coral reefs in the South Pacific: Taking stock of recent experience. *Journal of Environmental Management* 116(2013): 135-144.

Loewe, M. and N. Rippin 2015. The Sustainable Development Goals of the post-2015 agenda, comments on the OWG and SDSN proposals. German Development Institute, Bonn, Germany.

Milazzo, M. 1998. Subsidies in world fisheries: A re-examination. World Bank technical paper no.406. Fisheries series. Washington, DC: The World Bank.

Munro, G. and U. R. Sumaila 2002. The impact of subsidies upon fisheries management and sustainability: The case of the North Atlantic. *Fish and Fisheries* 3: 233–250.

Nicholson, E., B. Collen, A. Barausse, J. L. Blanchard, B. T. Costello, K. M. E. Sullivan, et al. 2012. Making robust policy decisions using global biodiversity indicators. *PLoS ONE*, 7(7), e41128.

OECD (Organisation for Economic Co-operation and Development) 1993. Indicators for the integration of environmental concerns into energy policies. OECD Environment Monographs No.79.

Pearce, D. W., A. Markandya, and E. B. Barbier 1989. Blueprint for a green economy Earthcan, London.

Pearce, D. W. and G. Atkinson 1993. Capital theory and the measurement of sustainable development. *Ecological Economics* 8: 103–108.

Pintér, L., P. Hardi, and P. Bartelmus 2005. Sustainable Development Indicators: Proposals for the way forward. http://www.iisd.org/pdf/2005/measure_indicators_sd_way_forward.pdf (accessed February 20, 2012).

Radermacher, W. 2005. The reduction of complexity by means of indicators – case studies in the environmental domain, in statistics, knowledge and policy: Key indicators to inform policy making, OECD.

Radermacher, W. and A. Steurer 2014. Do we need natural capital accounts, and if so, which ones? Eurostat (Paper for HLEG meeting, 22-23 Sept. 2014 in Rom).

Rickels, W., M. F. Quaas, M. Visbeck 2014. How healthy is the human-ocean system? *Environmental Research Letters* 9: 044013.

SDSN (Sustainable Development Solutions Network) 2015. Indicators and a monitoring framework for Sustainable Development Goals – Launching a data revolution for the SDGs. A report to the Secretary General of the

United Nations by the Leadership Council of the Sustainable Development Solutions Network (May 15, 2015). http://unsdsn.org/wp-content/uploads/2015/05/FINAL-SDSN-Indicator-Report-WEB.pdf

Scholtens, J., M. C. Badjeck 2010. Dollars, work and food: Understanding dependency on the fisheries and aquaculture sector. Presented at: IIFET 2010: Economics of Fish Resources and Aquatic Ecosystems: Balancing Uses, Balancing Costs. Le Corum, Montpellier, France July 13-16, 2010.

Selman, M., S. Greenhalgh, R. Diaz, Z. Sugg 2008. Eutrophication and hypoxia in coastal areas: a global assessment of the state of knowledge. WRI Policy Note 1: 1–6.

Smith, R., C. Simrad, and A. Sharpe 2001. A proposed approach to environment and sustainable indicators based on capital. Prepared for the National Round Table on the Environment and the Economy's Environment and Sustainable Development Indicators Initiative. http://www.oecd.org/dataoecd/18/12/33626361.pdf.

Statistisches Bundesamt (Destatis) 2012. Nachhaltige Entwicklung in Deutschland – Indikatorenbericht 2012. http://www.bundesregierung.de/Content/DE/Anlagen/Nachhaltigkeit-wiederhergestellt/2012-04-02-indikatorenbericht-2012-februar-aktualisiert.pdf? blob=publicationFile&v=1.

Sterner, T. and M. Persson 2008. An even sterner review: Introducing relative prices into the discounting debate. *Review of Environmental Economics and Policy* 2: 61-76.

Solow, R. M. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70: 65-94.

Sumaila, U. R. 2003. A fish called Subsidy. *Science and the Environment* 12(12). www.downtoearth.org.in/fullprint.asp.

Sumaila, U. R., A. S. Khan, A. J. Dyck, R. Watson, G. Munro, P. Tydemers, and D. Pauly 2010. A bottom-up re-estimation of global fisheries subsidies. *Journal of Bioeconomics* 12(3): 201-225.

Thompson, R. C., S. H. Swan, C. J. Moore, and F. S. vom Saal 2009. Our plastic age. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364(1526): 1973–1976.

Teh, L. C. L. and U. R. Sumaila 2013. Contribution of marine fisheries to worldwide employment, *Fish and Fisheries* 14: 77-88.

Traeger, C. 2013. Discounting under uncertainty: Disentangling the Weitzman and the Gollier effect. *Journal of Environmental Economics and Management* 66(3): 573–582.

UN (United Nations) 2015. Draft outcome document of the United Nations summit for the adoption of the post-2015 development agenda. Draft resolution submitted by the President of the General Assembly, Sixty-ninth session, Agenda items 13 (a) and 115, A/69/L.85, August 12, 2015. United Nations, New York, US.

UNECE (United Nations Economic Commision for Europe) 2014. Recommendations on Measuring Sustainable Development—Conference of European Statisticians. Prepared in cooperation with the Organisation for Economic Co-operation and Development (OECD) and the Statistical Office of the European Union (Eurostat). United Nations, New York and Geneva.

Visbeck, M., U. Kronfeld-Goharani, B. Neumann, W. Rickels, J. Schmidt, E. van Doorn, N. Matz-Lück, K. Ott, and M. F. Quaas 2014. Securing Blue Wealth: The need for a special Sustainable Development Goal for the ocean and coasts, Marine Policy 48: 184-191.

Appendix

Table A1: Overview about Indicators

Indicators proposed the UN Statistical Commission (2015) at the 46th session	**Indicators used in this study to assess sustainable oceanic development of EU coastal states**
Target 14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	
14.1.1 Fertilizer consumption (kg/ha of arable land)	*1. Gross N Balance*
14.1.2 Metric tons per year of plastic materials entering the ocean from all sources	*2.a Plastic Waste Generation* *2.b Recovery Rate of Plastic Packaging*
Target 14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	
14.2.1 Percentage of coastline with formulated and adopted ICM/MSP plans	*No indicator selected*
14.2.2 Ocean Health Index	*No indicator selected*
Target 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	
14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations	*3 Carbon emission*
14.3.2 Coral Coverage	*4 Natural Product (OHI)*
Target 14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	
14.4.1 Fish species, threatened	*5 Fish Species, threatened*
14.4.2 Proportion of fish stocks within biologically sustainable limits	*6 Fish stock biomass above BMSY*
Target 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	
14.5.1 Percentage area of each country's EEZ in MPA Percentage area of ABNJ in MPA Percentage area of global ocean under MPA	*7 Percentage area of each country's EEZ in MPA*
14.5.2 Coverage of protected areas	*8 Biodiversity (OHI)*
Target 14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	
14.6.1 Dollar value of negative fishery subsidies against 2015 baseline	*9 Government financial transfers to Marine Capture Fisheries relative to Gross Value Added*
14.6.2 Legal framework or tax/trade mechanisms prohibiting certain forms of fisheries subsidies	*10 Landings exceeding Total Allowed Catch*
Target 14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	
14.7.1 Fisheries as a % of GDP	*11 Coastal Livelihoods & Economics (OHI)*
14.7.2 Level of revenue generated from sustainable use of marine resources	*12 Tourism & Recreation (OHI)*
Target 14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	
14.a.1 Number of researchers working in this area	*13 Number of Marine Monitoring Stations relative to EEZ*
14.a.2 Budget allocated to research in the field of marine technology	*14 TAC Exceedance of Scientific Advise*
Target 14.b Provide access for small-scale artisanal fishers to marine resources and markets	
14.b.1 By 2030, X% of small scale fisheries certified as sustainable; Y% increase in market access for small scale fisheries	*15 Artisanal Fishing Opportunities (OHI)*
14.b.2 By 2030, increase by X% the proportion of global fish catch from sustainably managed small scale fisheries	*16 Fish stock harvest level below FMSY*
Target 14.c Ensure the full implementation of international law, as reflected in the United Nations Convention on the Law of the Sea for States parties thereto, including, where applicable, existing regional and international regimes for the conservation and sustainable use of oceans and their resources by their parties	
14.c.1 Adoption of a legal framework and number of associated court cases	*17 Participation rate in International Marine Agreements*
14.c.2 Number of countries implementing either legally or programmatically the provisions set out in regional seas protocols	

Table A2: Selected Indicators - Description, Source, and Transformation for the Assessment of Sustainable Oceanic Development of EU Coastal States

Indicator	*Detailed Description*	*Source*	*Period*	*Reference Value*
1 Gross N Balance	*Gross Nitrogen Balance per hectare UAA (kg of nutrient per ha)*	*Eurostat*	*2004—2012 (annual)*	*Max from 2004 until 2012 from all countries*
2.a Plastic Waste Generation	*Annual Plastic Waste generation (industrial and household) in kg/ head*	*Eurostat*	*2004—2012 (biannual)*	*Max from 2004 until 2012 from all countries*
2.b Recovery Rate of Plastic Packaging	*Plastic packaging waste recovery / Plastic packaging waste generated*	*Eurostat*	*2003—2012 (annual)*	*Dimensionless*
3 Carbon emissions	*CO2 kg/ capita*	*Eurostat*	*2004—2012 (annual)*	*Max from 2004 until 2012 from all countries*
4 Natural product		*OHI*	*2012-2014 (annual)*	*Dimensionless*
5 Number of fish species threatened	*Threatened fish species in each country (totals by taxonomic group)*	*IUCN (2015)*	*2014*	*Number of species in the EU*
6 Fish stock biomass above BMSY	*The reference BMSY is spawning stock biomass not total biomass*	*ICES*	*2012*	*Current SSB above or below BMSY*
7 Percentage area of each country's EEZ in MPA		*Natura 2000*	*2014*	*30 percent*
8 Biodiversity		*OHI*	*2012-2014 (annual)*	*Dimensionless*
9 Government financial transfers to Marine Capture Fisheries relative to Gross Value Added		*OECD, Eurostat*	*2006-2013 (annual)*	*Dimensionless*
10 Landings exceeding Total Allowable Catch	*Excess Landing over total catch relative to TAC (in tons)*	*ICES*	*2000 – 2013 (annual)*	*Deviation from 100*
11 Coastal Livelihoods & Economics		*OHI*	*2012-2014*	*Dimensionless*
12 Tourism and Recreation		*OHI*	*2012-2014*	*Dimensionless*
13 Number of Marine Monitoring Stations relative to EEZ		*ICES/ EIONET/ EEA*	*2012*	*Average of stations*
14 TAC Exceedance of Scientific Advise		*ICES*	*2000-2013 (annual)*	*Deviation from 100*
15 Artisanal Fishing Opportunities		*OHI*	*2012-2014 (annual)*	*Dimensionless*
16 Fish mortality (FMSY)	*Fishing pressure indicator*	*ICES*	*2012*	*Current F value above or below FMSY*
17 Participation rate in International Marine Agreements		*Wolfram Alpha*	*2014*	*Number of Agreements*