The Ocean Health Index Conceptual Guide

Contents

1 Need for and Benefits of an Ocean Heath Index

Marine management mandates in the current financially constrained environments are increasingly requiring the establishment of comprehensive management objectives that maximize sustainable production while maintaining healthy oceans. This requires a cycle of measuring conditions, developing and enacting strategic responses, and continuous monitoring. The Ocean Health Index (OHI, or the 'Index') was developed to support this growing need by providing a framework that quantifies overall ecosystem health, which can be tailored to any spatial context, both political and ecological. The Index is the first assessment tool that provides a common platform for scientifically combining and comparing key elements from all dimensions of the oceans health — biological, physical, economic and social – to measure how sustainably people are using the ocean. The Index provides a tool to measure and track changes in several ocean and coastal dimensions through a repeatable, transparent, quantitative, and goal-driven approach. It was developed as a framework to assess coastal oceans in a formulaic manner, and was designed to be customizable to different spatial scales, data availability, and cultural priorities. As a management tool, the Index can help inform decision-making by helping stakeholders identify geographic and thematic priorities, which increases the cost-effectiveness of management interventions.

Overall Index scores are a combination of ten components, or 'goals', of ocean health. These scores are calculated using the best available data and indicators at the scale of the assessment. Scores reflect how well coastal regions optimize their potential ocean benefits and services in a sustainable way relative to a reference point (or target), on a scale of 0 to 100. By combining ocean and coastal benefits under a single framework, the Index allows for a comprehensive and integrated view of marine systems as well as a better understanding of potential trade-offs or synergies among these goals. This structured, but highly tailorable, framework provides a consistent platform from which to conduct assessments through time, and at any spatial scales desired.

While many indices have been created to track particular issues or trends in economics, social science or environmental quality, the Index is the first to define and track ocean health comprehensively. It recognizes that people are part of the ocean ecosystem, evaluates how well the ocean provides ten key benefits to people now, and how well we protect its ability to do so in the future. This index differs from typical indicator-based monitoring systems, be they small, such as managing a seafood farm, or large, such as the Millennium Development Goals. Those systems typically contain a list of indicators each of which assesses performance in a particular task or topic. Performing successfully in many or all categories undoubtedly improves overall performance, but does not provide information on the relationship between the different indicators and sectors evaluated.

As a composite index, the Index integrates the results for and relationships between all categories that it evaluates. By integrating information from many different disciplines and sectors, the Index represents a significant advance over conventional single-sector approaches to assessing ocean condition. Because the information from the Index can help inform decision-making in terms of identifying cost-effective management interventions to improve ocean health, it addresses the desire of increasing environmental performance in the face of tightening budgets for natural resource management and conservation.

2 Task Timeline

The Task Timeline provides the steps involved in conducting Ocean Health Index assessments. It also suggests the types of skills required while doing so. The process of calculating the Index is not necessarily linear: there is a lot of iteration and discussion among the team to make the best decisions. For example, gathering appropriate data for each status, pressure, and resilience layer requires thinking about how to calculate their reference points at the same time. It is possible that data sources will need to change during the process and goal models will have to be modified as well.

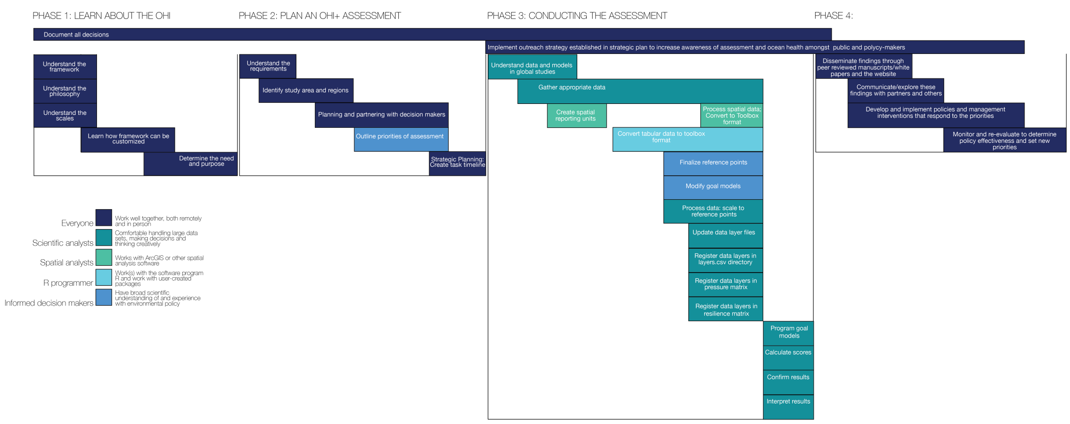

Figure 1: A timeline of the OHI+ assessment process.

The Task Timeline outlines four phases that occur through time. The time required will depend on the availability of data, the number of people working on the assessment, as well as challenges that may arise. Tasks are indicated by skill set but many decisions will also occur as a team.

The phases and tasks outlined in the Task Timeline are:

- **Phase 1:** Learn about the OHI
- **Phase 2:** Plan an OHI+ Assessment
- **Phase 3:** Conduct the Assessment
- **Phase 4:** Outreach and Communications

For more information, visit: http://ohi-science.org which is continually updated.

3 Phase One: Learn about the Ocean Health Index

There are four distinct and interconnected phases in the Ocean Health Index assessment process. This document describes Phase One.

In this section you will learn how to:

- Determine the need and purpose of your assessment as well as ways to leverage ongoing efforts

- Plan and partner with decision makers
- Who should be involved?
- Conduct a stakeholder analysis
- Introduce the OHI+ concept to key stakeholders

- Understand the requirements of running an Ocean Health Index assessment
- Funding
- Data Requirements

- Understand the OHI philosophy
- Methods
- Resources

- Design adaptive management strategies

- Structure an outreach and communications strategy around the assessment

The recommended process and criteria presented in this section offer a systematic approach to leveraging existing efforts in to the Index. The way information is incorporated depends on what is most appropriate for the region conducting the assessment, which requires considering local conditions and capacities.

3.1 What is the Ocean Health Index?

The Ocean Health Index defines a healthy ocean as one that can sustainably deliver a range of benefits to people both now and in the future. A healthy ocean in this definition is not necessarily a pristine ocean, although the Index allows for pristine systems as well as sustainably used systems to score highly. The benefits provided by the ocean are captured by the following ten broadly held public goals:

- **Food provision** from sustainably harvested or cultured stocks
- **Artisanal opportunities** for local communities from sustainable practices
- **Natural products**, including pharmaceuticals and decorative materials, that are sustainably extracted
- **Carbon storage** in coastal habitats
- **Coastal protection** from inundation and erosion
- **Sense of place** from culturally valued iconic species, habitats, and landscapes
- **Livelihoods and economies** from coastal and ocean-dependent communities
- **Tourism and recreation** opportunities
- **Clean waters** and beaches for aesthetic and health values
- **Biodiversity** of species and habitats

3.2 Food Provision

The aim of this goal is to maximize the sustainable harvest of seafood in regional waters from **Wild-Caught Fisheries** and **Mariculture** (specifically, ocean-farmed seafood). Regions are rewarded for maximizing the amount of sustainable seafood provided and they are penalized for unsustainable practices or for under-harvest. Because fisheries and mariculture are separate industries with very different features, each is tracked separately as a unique sub-goal under **Food Provision**. They are then combined after each sub-goal is weighted by the proportion of the total yield it contributes to total food provision.

- ### 3.2.1 Wild-Caught Fisheries

  This sub-goal captures the amount and sustainability of wild-caught seafood harvested primarily for human consumption. It measures the ability to obtain maximal wild harvests without damaging the ocean's ability to continue providing similar quantities of fish for people in the future.

  Wild-caught fisheries harvests must remain below levels that would compromise the resource and its future harvest, but the amount of seafood harvested should be maximized within the bounds of sustainability. This is a departure from traditional conservation goals regarding wild-caught fisheries where under-harvesting is usually not penalized. This sub-goal can interact with other goals and sub-goals through, for example, destruction of surrounding habitats that can indirectly decrease the productivity of the fisheries.

  Ideally, data for catch and effort of every commercially - and recreationally-fished species would be available, as well as the functional relationship between fish population size (biomass) and fisheries effort, so that maximum sustainable yield (MSY) could be calculated. Then, fisheries catch and effort information would be used to calculate the present state and MSY would be used to set the reference point. Current status would be calculated using the present state of every individual species and combining each species together, as the weighted proportion of total catch.

- ### 3.2.2 Mariculture

  This sub-goal measures the ability to obtain maximal seafood yield from farm-raised facilities without damaging the ocean's ability to continue providing fish for people in the future.

  Mariculture practices must not inhibit the future production of seafood in the area. This means mariculture practices must be sustainable and also maximize the amount of food production that is physically possible and desired by regional governments and those who buy, sell and eat that food.

  Ideally, there would be information on the physical area available for mariculture - or the area allowed based on social expectations and priorities - and the sustainability of the mariculture practices. This would mean that data are available for the physical coastal and offshore habitat appropriate for each intended type of mariculture service (for instance, offshore habitats marked as appropriate for finfish and shallower habitats for filter-feeding invertebrates) and that the areas have been identified as socially appropriate. The social component is important in this case because mariculture competes for space with many other ocean uses, including fishing and tourism activities. This approach would not penalize regions that have less geographic area available for mariculture, though places with fewer sheltered bays or lower primary production could be at a disadvantage compared to places that have more favorable conditions. The type of reference point used will depend on the data available.

3.2.3 Practical Considerations

Lessons Learned (2014)

This goal model measures the amount of seafood sustainably harvested in a given region for primarily human consumption. It should include quantity of fish caught by any practice including wild-caught commercial fisheries, mariculture, artisanal-scale fisheries and recreational fisheries.

3.2.3.1 Recommendations for regional assessments The overall Food Provision model should not change: it should always measure whether the seafood from fisheries and mariculture (if it is practiced) is harvested at maximum carrying capacity while remaining sustainable. The contribution of each practice to the overall score is weighted by its relative contribution to the total seafood yield. So far we have only been able to assess commercial fisheries and mariculture with this model. However, if another component were added, for example artisanal fisheries, one might want to consider different options for how to combine it into the indicator. Is a ton of fish harvested through artisanal fisheries equivalent to a ton harvested commercially? Currently, this is the assumption for the Food Provision. But if there is solid rationale to use a different approach, using a different approach to calculating the goal is within the abilities of the OHI.

3.2.4 MARICULTURE

3.2.4.1 Practical Considerations

3.2.4.2 Recommendations for regional assessments Setting the reference point for mariculture really depends on regional preferences. This can be very hard to do: in best cases you would incorporate the potential range for mariculture based on habitat suitability for each cultured species, distance from the coast as well as which habitat is suitable, and how much local preference wants to allot to mariculture (versus area apportioned to ports, hotels, beaches, tourism, etc). In Global 2012, without information about social limitations for how much coastal area could be allotted to mariculture, we included the entire area of the coastline, thus assuming that mariculture could be developed everywhere. At a regional scale, better data will allow for restrictions based on habitat, conflicting uses, and social preferences.

3.2.4.3 *Ideal Approach* Ideally, there would be information on the area available for mariculture - physically and/or based on social expectations and priorities - and the sustainability of the mariculture practices. This would mean that assessments had been made to identify the physical coastal and offshore habitat appropriate for each intended type of mariculture species (example: offshore habitats for finfish and shallower habitats for filter-feeding invertebrates) and the areas that have been identified as socially appropriate, since mariculture competes for space with many other ocean uses, including fishing and tourism activities. This approach would not penalize regions that have less geographic area available for mariculture, though places with fewer sheltered bays or lower primary production could be at a disadvantage. The type of reference point used will depend on the data available.

3.2.4.4 *History of the Approach (lessons learned 2014)* This sub-goal aims to capture if maximal seafood yield from farm-raised facilities is occurring without damaging the ocean's ability to continue providing fish for people in the future.

3.2.4.5 Model description Global 2012: Mariculture was calculated as the yield reported to the United Nations Food and Agriculture Organization (FAO) multiplied by the sustainability for each species harvested.

Global 2013: A similar model to the one developed previously in Global 2012 was used in Global 2013; however, since we modified the approach to setting the reference point, the calculation of the results has significantly changed.

Brazil: The status of the Mariculture sub-goal was calculated using harvest data reported by the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA). For each of up to four species cultured within the state, the score was determined by the yield, the reference sustainable production per unit area, and the total potential farming area.

US West Coast: The status of the Mariculture sub-goal was calculated as the sustainable production density of shellfish biomass from mariculture relative to a target level of production density for each state within the region. Evolution of the approach:

Global 2012: At the global scale it was not possible to account for all physically appropriate habitats where mariculture could occur, and thus the entire area within 3nm from the coastline was considered potential habitat, although it is clear that that entire habitat is not physically suitable for mariculture, nor would it be socially desirable to do so. However, restricting the area based on biophysical constraints and social preferences at a global scale was not possible. Gauging mariculture sustainability was difficult and was ultimately based on information from a Mariculture Sustainability Index (MSI) by Trujillo (2008). The MSI incorporated information on wastewater treatment, origin of feed (i.e. fishmeal or other) and the origin of seed (i.e. hatchery or wild caught). The MSI, however, was not recalculated after 2005 and, when missing, values from other regions or from related species had to be used.

Global 2013: Global 2013 differs from Global 2012 due to the reference point; see below.

Brazil: Locally cultured species were used to calculate scores and appropriate reference points were set for each species state.

US West Coast: Better information about physical and social limitations on mariculture allotments was available for the regional study in the US West Coast. The US government has identified areas that are appropriate for mariculture based on current water quality and coastal development, and thus mariculture production was assessed only within these predefined areas, and not for the entire coastline as was done in Global 2012. In addition, a target level of production increase was proposed by the ocean government agency that was used to set the reference point.

3.2.4.6 The reference point

*Global 2012:** The reference point is based on the goal for each region to produce as much farmed seafood as sustainably possible within its coastal area. The reference point for mariculture is a spatial comparison (and not a theoretical functional relationship for sustainable production yield as there is for wild-caught fisheries), set at the amount of seafood produced per square kilometer of eligible coastline in the most productive region, which, at the time of the global study, was China. Setting a spatial reference point in this way assumes that because China is able to produce such a high proportion of mariculture to its coastal area, all regions should be able to as well, given current ecological and technological conditions. This also assumes that it is socially desirable for all regions to produce farmed species at this level, which is likely not true for all regions.

Global 2012 compared all areas to that with the highest observed production density after the sustainability coefficient was applied, based on the assumption that all coastal area in each region could be developed for mariculture at the same production density as the reference region (i.e., China) and that maximum potential productivity per unit of area is similar across ecosystems and regions. This caused regions with extensive proportions of coastline where mariculture is unsuitable for biological reasons (e.g. the water freezes for large part of the year) or logistical reasons (e.g. scarcely inhabited), such as Canada, to be unduly penalized.

Global 2013: Global 2013 instead bases the reference point on harvested tonnes per coastal inhabitant (with coastal defined as within 25 km inland), under the assumption that production depends on the presence of coastal communities that can provide the labor force, infrastructures, and economic demand to support the development and economic viability of mariculture facilities. Thus, two regions with an equal number of coastal inhabitants harvesting an equal tonnage of cultured seafood should score the same, even if one is larger than the other, as the productivity is commensurate to each region's socio-economic potential to develop mariculture. Stated another way, mariculture development is assumed to scale proportionally with coastal population as a proxy for local demand and potential logistic limitations to farm development, e.g., presence of infrastructures, coastal access, and locally available workforce. Given the very high skew in the status values per region, we set the reference point to the 95th percentile region (Thailand), with all regions above that value set to a status score = 1.0

Brazil: At the regional scale in Brazil, restricting the area available for Mariculture based on biophysical constraints and social preferences was possible.

US West Coast: For the mariculture sub-goal, the reference point was modified to incorporate local information on suitable areas for cultivation and desirable production targets, proposed by the US government agency responsible for marine resources management (NOAA). This is a case where conceptually the US West Coast approach is similar to Assessments 1 and 2 but the reference point is based on better information.

3.2.4.7 Interpreting a score Higher scores reflect high food provisioning in a sustainable manner, while not compromising the water quality in the farmed area and not relying on wild populations to feed or replenish the cultivated species. A score of 100 means that a region is sustainably harvesting the greatest amount of farmed seafood possible based on its own potential (where its maximum potential is estimated in different ways depending on the assessment. A low score can indicate one of two things – that species are being farmed in an unsustainable manner or that regions are not maximizing the potential to farm in their marine territorial waters.

3.2.5 WILD-CAUGHT FISHERIES

3.2.5.1 Practical Considerations

3.2.5.2 *Ideal Approach* Ideally, data for catch and effort of every commercially- and recreationally-fished species would be available, as well as the functional relationship between fish population size (biomass) and fisheries effort, so that maximum sustainable yield (MSY) could be calculated. Then, fisheries catch and effort information would be used to calculate the present state and MSY would be used to set the reference point. Current status would be calculated using the present state of every individual species and combining each species together, as the weighted proportion of the total catch.

History of the Approach (lessons learned 2014)

Wild Caught Fisheries This sub-goal model aims to assess the amount of wild-caught seafood that can be sustainably harvested, with sustainability defined by multi-species yield, and with penalties assigned for both over- and under-harvesting. Penalizing for both over- and under-harvest is different from the way fisheries are normally assessed, where penalties are strictly for overharvest, since this is the information that is directly relevant to fisheries managers. In our case, since we need to assess the delivery of a benefit compared to an optimum, it makes sense to also consider the potential benefit that is not achieved by underharvesting. So far, we have not created assessments of this model that capture food security. In other words, this goal assesses whether seafood is being harvested in a given region, but does not track where or by whom it is consumed, and it does not assess nutrition quality. Potentially, the outcome from assessing the Food Provision goal could be used as input if a food security assessment were developed. Recommendations for regional assessments: Use catch-per-unit effort data if available, and a functional relationship for the reference point. Fisheries modeling using data poor sources was greatly improved in Global 2013 than the original approach in Global 2012. If regional assessments rely solely on catch data, it is highly recommended to use Global 2013 and not Global 2012.

The degree to which under- versus over-fishing are penalized is a subjective matter that depends on what management strategies are considered ideal and on in-depth understanding of species-specific resilience to fishing pressure. This approach may change in the future as more established strategies emerge. Similarly, the degree to which under-reporting or coarse level reporting is penalized in assigning the score can be a subjective matter. We lower the score when catch data is not reported at species level because 1) we assume this implies that the species is not being monitored and thus is unmanaged, and 2) we see this as an incentive to encourage monitoring these species more closely and thus improving overall management in the region. In the future, the degree to which coarsely reported catch reflects poor status of the resources, and the level of penalty warranted by lack of information are both decisions might rest on well established practice. Model description: Global 2012: Status of the Fisheries sub-goal was calculated as a function of the absolute difference between a region's total landed biomass from the reference multi-species maximum sustainable yield weighted by a correction factor that adjusts for taxonomic reporting quality of the data.

Global 2013: Status of the Fisheries sub-goal was calculated based on estimating population biomass relative to the biomass that can deliver maximum sustainable yield for each landed stock (B/BMSY). The estimates of B/BMSY were obtained by applying a model developed by Martell & Frœse, (2013), and referred to as the "catch-MSY" method. This ratio is conventionally used to inform fisheries management.

Brazil: Status of the Fisheries sub-goal was calculated in the same manner as Global 2012, with a modified sustainability term.

US West Coast: Status of the Fisheries sub-goal was based on population biomass relative to the biomass that can deliver maximum sustainable yield (B/BMSY) and fishing mortality relative to fishing mortality that can deliver maximum sustainable yield (F/FMSY) for each landed stock, using formal stock assessments rather than relying solely on data-poor estimates from catch data. These ratios are conventionally used to inform fisheries management. Evolution of the approach: Better methods for data-poor stocks have been developed in Global 2013, improving upon those developed for Global 2012. When better data are available and local experts have produced formal stock assessments, better-informed models can be developed, as was done in US West Coast.

Global 2012: At a global scale, catch, effort, and MSY estimates are not available for either commercial, artisanal or recreational fishing: only landings data for commercial fisheries are available through the United Nations Food and Agriculture program (UN FAO). Thus, within the aims of the wild-caught fisheries goal, the ideal approach had to be modified to be appropriate for the data that were available. Working with fisheries scientists to adapt the ideal approach, data from all commercially fished species in a region were used to estimate the MSY for each species and were combined to obtain a reference point of multispecies MSY.

Global 2013: Since Global 2012, several new data-poor approaches have been developed to assess fisheries that leverage globally-available information (Costello et al., 2012; Martell & Frœse, 2013; Thorson et al., 2013). The catch-MSY approach improves upon the method used in Global 2012 in that it leverages a mechanistic understanding of the connection between harvest dynamics and population dynamics and uses this to infer stock depletion levels as a function of both historical patterns in catch and of species-specific resilience traits (see also Thorson et al. 2013). In addition, this model is more informative in the case of developing fisheries, whereas the previous approach assumed a perfect score in cases where a peak with successive decline had yet to be observed. The "catch-MSY" model, as designed by Martell & Frœse, calculates catch/MSY. For our analyses, we converted this to an estimate of B/BMSY, i.e. an indicator of stock abundance rather than catch, which is more directly informative of stock heath. This more complex (although still data poor) approach better takes into account species-specific fishery dynamics. In addition, the scores for each population were combined using a geometric mean, which ensures that smaller, rarer populations have more weight and thus biodiversity of the catch is taken into account as well. As before, regions are penalized for underharvest and (more severely) for overharvest.

Brazil: The fisheries sub-goal was calculated in the same manner as Global 2012; this study was conducted before improvements to the approach (Global 2013). However, local-scale data on exploitation category of species caught within Brazil's EEZ was used as catch-based sustainability index, an improvement over the original Global 2012 approach.

US West Coast: Stock assessments were only available for 41 different species across the whole study area. These 41 species accounted for ~59% of the total average catch across the catch time series data. We tested the use of a recently published data-poor approach (Costello et al. 2012) to obtain B/ BMSY values for the remaining stocks. To validate the results we compared estimates for which we had formal stock assessment values and found the latter to be outside the confidence bounds predicted by the model. Other estimates of overfishing are available for data poor stocks (Dick & MacCall 2010), however these only cover ~2% of overall catches. Therefore, our analyses were only based on values from assessed stocks.

From each assessment we extracted the estimates for B/BMSY and F/FMSY that are assigned to the whole species throughout the west coast of the US. Fisheries scores were then assigned to each region based on the contribution of each species in each region to the overall catch in that region. These weights were assigned based on the average catch of each species across all years of recorded catches (1950-2011). This means that each species gets a single score in the overall study area, and what differentiates the scores from region to region is which species are in that area and how much they contribute to the area's average historical catch. We used the average catch over time instead of current catch as a weighting factor as it reflects the mean potential contribution of each species to total food provision, smoothing over stochastic fluctuations and possible recent declines. Catch data were only available at the state level, so all regions within California received the same status score. The reference point: The reference point is set with a functional relationship. Regions are penalized for resources that are either underfished or overfished, as both of these conditions detract from the overall achievement of maximized food provision.

Global 2012: The reference point is based on an estimate of the optimum amount of all marine species that may be caught sustainably, minimizing the likelihood of overfishing while maximizing harvest, i.e. the multispecies MSY (mMSY). This was calculated by summing all the single-species MSY estimates obtained for commercially landed species. The reference point for wild-caught fisheries was set at 25% below mMSY to take into account that mMSY may be overestimated because single-species estimates of MSY obtained under current conditions may change. Indeed, when all species are exploited simultaneously, the fishing pressure that each population can withstand might be lower (or higher) due to changes in interactions between species, e.g. if a prey population is reduced, a predator may not be as abundant as predicted by the single species model (or vice versa for the prey species, in the case of a predator species becoming less abundant). By picking a lower reference point, we adopt a precautionary estimate of the total amount of seafood that could be sustainably caught. In other words, the reference point is set so the total landed biomass of wild-caught species will not be more than 75% of the estimated mMSY. Regions are penalized for harvests above or below this reference level (more heavily if above).

Global 2013: This approach adopts the population biomass at MSY (BMSY) as a single-species reference point, which by various assessment frameworks is considered conservative (e.g. Frœse et al. 2011). Single-species values of B/ BMSY are aggregated using a geometric mean ensuring that some multi-species effects may influence the scores. This is a more direct measure of population health because it relates directly to population size, rather than the harvested biomass of those populations. More importantly, this reference point was calculated through a more robust model than the one used in Global 2012, published by Frœse & Martell in 2013.

Brazil: As in Global 2012, the reference point is based on an estimate of the optimum amount of all marine species that may be caught sustainably: mMSY.

US West Coast: This approach adopts the population biomass at MSY, i.e. BMSY, as a single-species reference point, in combination with the fishing mortality at maximum sustainable yield, i.e. FMSY. Interpreting a score:

Higher scores reflect fishing practices with sustainably high yields that avoid excessively high exploitation (i.e. overfishing), and do not target threatened populations.

For Global 2012 and 2013, the formulae show that a stock receives a score of zero if either it is completely depleted, i.e. B/BMSY = 0, or strongly underfished, i.e. B/ BMSY = 3.35, with 3.35 representing the local currently observed maximum value. Any past or future B/ BMSY values greater than 3.35, as well as the species with this maximum value, would receive a zero score for food provision to denote that the species is severely underfished. However, given that underutilization of resources is generally easier to remediate than depletion, we apply an asymmetrical buffer around values of B/ BMSY close to 1 that get assigned a perfect score, (i.e., overfished stocks achieve a perfect score if B/BMSY is up to 0.2 points below 1 but underfished stocks achieve a perfect score if B/BMSY is within 0.5 points of 1). Thus, overfished species negatively influence the long-term sustainable delivery of the food provision goal more than underfished species do. For the US West Coast, combining F/FMSY with the population size compared to the size that ensures MSY (B/BMSY) allows us to take into consideration how it is currently being exploited. A population that is dwindling, but is also not under heavy fishing pressure, has more chances of recovering and so it receives a higher score than one that has a similar B/BMSY but is also under strong fishing pressure, thus being most likely to continue in its decline in the near future. On the other hand, a population that is abundant, but has a low F/FMSY, is not being exploited to its full potential and thus its score gets partially penalized due to this underutilization. This approach produces lower scores for species where both underfishing and overfishing are occurring, but does not punish as severely for underfishing of stocks.

3.3 Artisanal Fishing Opportunities

This goal captures whether people with the desire to fish on small scales have the opportunity to do so. It is important to capture the degree to which a region permits or encourages artisanal fishing compared to the demand for such fishing opportunities, and if possible, the sustainability of artisanal fishing practices.

The artisanal fishing opportunities goal measures the opportunities for artisanal fishing rather than the amount of fish caught (covered in the **Food Provision** goal) or the household revenue earned (covered in the **Livelihoods and Economies** goal). Higher scores reflect high potential for the local population to access local ocean resources, regardless of whether or not those people actually do get access. This goal is about economic access (need and costs involved), as well as physical access (how possible it is for individuals to get to the resource), and access to the fish themselves (how robust fish populations are). The opportunity to fish artisanally interacts with other goals when damaging practices are used (for example, cyanide or dynamite fishing).

Ideally, this goal would include some measure of how easy or hard it is for people to access ocean resources when they need them and a quantified evaluation of the sustainability of harvest of all nearshore stocks used by artisanal fishermen. The type of reference point used will depend on the data available.

3.3.0.3 Practical Considerations

3.3.0.4 ***Ideal Approach*** Ideally, this goal would include some measure of how easy or hard it is for people to access ocean resources when they need them and an assessment of the (un)sustainability of harvest of all nearshore stocks used by artisanal fishermen. The type of reference point used will depend on the data available.

3.3.0.5 Recommendations for regional assessments Regional assessments will likely modify the model using different or better-resolved data. This goal should be based on access: physical, economic, regulatory, and availability of stocks—as much as data allow. A combination of all of these would be best.

3.3.0.6 ***History of the Approach (lessons learned 2014)*** This goal captures the access people have to coastal resources, whether or not they actually do fish in coastal waters. The amount of seafood caught, if reported, is contained within the Food Provision goal (or possibly the Natural Products goal); and any wages or revenue, are not included here but instead in the Livelihoods and Economies goal. Instead, this goal specifically tries to estimate whether individuals or households have the access to the sea that they need for their own survival. Status for this goal is estimated as a function of need for artisanal fishing opportunities and whether or not the opportunity is permitted and/or encouraged institutionally, and whether artisanal fishing could be sustainable. It measures the potential for artisanal fishing whether or not this potential is actually met.

3.3.0.7 Recommendations for regional assessments Regional assessments will likely modify the model using different or better-resolved data. This goal should be based on access: physical, economic, regulatory, and availability of stocks—as much as data allow. A combination of all of these would be best.

3.3.0.8 Model description

Global 2012: Status for this goal is measured as the demand for opportunities to fish artisanally. Demand is estimated using poverty levels as proxy, measured by the gross domestic product (GDP) per capita, adjusted by the purchasing power parity. The supply was estimated using an indicator that ranked how well regions regulated and supported artisanal fishing, as part of a study by Mora et al. (2009). This assessment did not incorporate a measure of the health of the targeted species or of sustainability of the fishing practices as a standardized artisanal harvest database was not available at a global scale.

Global 2013: Same as Global 2012

Brazil: Economic or physical access/demand to fishing were not deemed to reflect circumstances in Brazil, and therefore this simplified model reflects that the primary driver of artisanal fishing opportunity is the availability of fish to capture (i.e. the condition of the stocks).

US West Coast: We developed a model using physical and economic access to coastal areas and access to the biological resources through the effectiveness of fisheries management as key variables. This approach does not model demand, but simply assumes that as long as there are no obstacles to pursuing artisanal fishing, the goal is fully achieved. These data better capture the nature of small-scale fisheries in the study area (artisanal, subsistence, and small-scale commercial) whereas the global model focused essentially on subsistence fishing.

3.3.0.9 Evolution of the approach

Global 2012: The need for artisanal fishing could potentially be driven by any number of socio-economic factors, but perhaps the most wide-spread reason is the need for food either directly or through undocumented local trade which correlates well with poverty level. Data on how many people live below the poverty level are not available for many regions. Therefore, we used an analogous proxy that is more complete globally: per capita gross domestic product (pcGDP) adjusted by the purchasing power parity (PPP). Because no time series data were available for the access to artisanal fishing measured in the study by Mora et al. (2009), the trend was actually solely driven by the change over time in the PPPpcGDP, i.e., how 'demand' is changing over time. The sustainability of artisanal fishing practices could be approximated by using the status of the species that are targeted by artisanal fishermen. Unfortunately data on harvest from artisanal fisheries are often unavailable so we were unable to include this term in the calculation of this goal; we include it here for conceptual completeness.

Global 2013: Same as Global 2012.

Brazil: In Global 2012 artisanal fishing opportunity was assessed as a function of the need and the accessibility with a place-holder for stock status (which could not be assessed at global scales for artisanal-scale fishing). For Brazil the primary driver of artisanal fishing opportunity is the availability of fish to capture (i.e. the condition of the stocks). Because the scale of analysis for which we had stock status information was national, we chose not to include a measure of artisanal need (levels of poverty), which has great variation within Brazil. In addition, we assume that access to fishing is largely open because permitting and regulations from the Ministry of Fisheries are not considered restrictive, and in most cases, neither is physical access.

US West Coast: There are no data available on the number of people actively participating in artisanal fishing activities, nor a good approximation of what a reasonable reference condition would be that would allow to model 'demand' for artisanal fishing opportunities were these data available. Instead, we only consider physical and economic access to fishing opportunities and to the biological resources by assessing the condition of targeted fish stocks in the region, focusing exclusively on whether artisanal fishing opportunities are being fully provided in the region. This approach differs from the Global 2012 and 2013 assessments, where artisanal fishing opportunities were assessed as a function of need (based on the level of poverty present in a region) and the effectiveness of small-scale fisheries management in satisfying this need, mainly focusing on artisanal opportunities for subsistence purposes. It is also important to note that we were able to incorporate the accessibility to the desired species (i.e. status of the targeted stocks) only in this assessment because of data availability, but ideally we would've included this also in Global 2012 and 2013.

3.3.0.10 The reference point Global 2012: The reference point for artisanal fishing opportunities is that all demand for artisanal fishing is allowed and/or achieved and that the fishing is done in a way that doesn't compromise future fishing resources. Thus, the reference point is that 'supply' (i.e. fisheries regulations as measured by Mora et al. (2009)) is greater than demand so that unmet demand is 0, i.e. all demand for artisanal fishing is allowed and/or achieved.

Global 2013: Same as Global 2012.

Brazil: This model was based solely on the sustainability index calculated using the exploitation status of species. The reference point for artisanal fishing opportunities is an established target of 1.0, that is, all stocks are categorized as either Developing or Fully Exploited. Due to the widespread nature of artisanal fisheries throughout Brazil, and the major contribution of small-scale activities to total landings for the country, all species were considered possible targets of artisanal fishing activities.

US West Coast: Members of the public in the region fish artisanally from shore-based coastal access points (like beaches and jetties) as well as from boats. The key variables affecting access to these two modes of artisanal fishing differ and so we treat them separately in our assessment. Shore-based fishing is primarily constrained by physical access to fishing locations and is thus measured as percent of coastline within a mile of coastal access points. The target here is to maximize the amount of public access along the coast, therefore a perfect score results when each part of a region's coastline has a coastal access point within 1 mile. We calculate these scores using a raster allocation model with 1-mile resolution intersecting at the coastline.

3.3.0.11 Interpreting a score A score of 100 means that a region is addressing and meeting the needs that people and communities have to fish artisanally by implementing government policies that permit or encourage them to do so, providing appropriate access to near-shore areas, and maintaining the species targeted in good health. A low score indicates that regions are not achieving or allowing sustainable artisanal fishing opportunities to be realized.

3.4 Natural Products

This goal captures how sustainably people harvest non-food products from the sea.

Natural Products uses the amount of ocean-derived goods that are traded, such as shells, sponges, corals, seaweeds, fish oil, and ornamental fishes to evaluate their levels of sustainability. Higher scores reflect sustainable extraction of non-food ocean resources with little to no impact on surrounding habitats, marine species, or human well-being.

Ideally, quantity, value, and the sustainability of the harvest method would be available for every marine and coastally-derived natural product within the regions of a study area. This would include a wide range of products, including corals, shells, seaweeds, aquarium fish, mangrove wood, or any non-food marine product that is harvested within a region. The ideal reference point would be derived from a functional relationship of the sustainability of the harvest for each product relative to the amount of product available in the ecosystem; without this information assumptions will need to be made to set the reference point.

3.4.0.12 What it does not include This goal does not include non-living items such as oil, gas, and mining products, because these practices are not considered to be sustainable, and they are done at such large scales that including them would essentially make an index for oil and mining. It also does not include bioprospecting (for medicines or genes), which has an unpredictable potential value in the future, rather than measurable value now. This goal can interact with other goals and sub-goals when unsustainable harvesting practices are used.

3.4.0.13 Practical Considerations

3.4.0.14 ***Ideal Approach***

Ideally, quantity, value, and the sustainability of the harvest method would be available for every marine and coastally-derived natural product within a region. This would include a wide range of products, including corals, shells, seaweeds, aquarium fish, mangrove wood; any non-food marine product that is harvested within a region. The ideal reference point would be a functional relationship of the sustainability of harvest for each product; without this information assumptions will need to be made to set the reference point.

3.4.0.15 Recommendations for regional assessments

The kinds of marine products included, and how much should each contribute to the overall score may vary from case to case and should be decided based on the data available (see model details below in Evolution of the Approach). For example, if seaweed is a natural product, but it is also food, if there are no data to indicate the proportions of these two uses, some other source of information will have to be used to decide what proportion should be used to calculate Food Provision and what proportion should be computed for Natural Products. As another example, oil from marine mammals was excluded from the models presented here, but if a region has a considerable amount of mammal oil harvest, they should include it in the calculation, keeping in mind that the sustainability of this type of harvest is likely to be low and should be reflected in the score.

It is possible to measure sustainability in a number of different ways. Quantitative information can be used, or expert judgment, perhaps based on information or rough estimates of how sustainable the harvest method is, which is what was done in Global 2012. We based the sustainability component on the historical maximum harvest recorded, the maximum harvesting density recorded, and risk status assessments by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Ideally, both the maximum sustainable harvest levels and the sustainability coefficient would be based on functional relationships obtained from specific studies. In the absence of these, we borrowed general principles from fisheries models to provide rough estimates.

product	relative tonnes (1)	weighting (2)	Exposure (3)	Risk (4)
coral	FAO	FAO	coral habitat	all 1
sponges	FAO	FAO	coral + rocky reef habitat	all 0
ornamentals	FAO	FAO	coral + rocky reef habitat	1 if blast/cyanide fishing, otherwise 0
fish oil	FAO	FAO	fish score/100	–
shells	FAO	FAO	coral + rocky reef habitat	all 0
seaweeds	FAO	FAO	rocky reef habitat	–

3.4.0.16 Data overview

(1) relative tonnes: tonnes relative to max tonnes for region with 35% buffer. The maximum corresponds to the year with the highest $ value - but it would probably be better to just base this off tonnes. When we redo these data lets evaluate this approach.

(2) weighting: This weights the contribution of each product according to USD at max year for a region. It makes sense to use $, because comparing extraction weight of sponges vs. ornamentals doesn't make sense.

(3) Exposure: For fish oil this value is the FIS score (which is a bit different than what is described in the paper because FIS score can have penalties for underfishing). The other values are determined by: log (harvest/habitat area + 1) / log[max(harvest/habitat area) +1].

The habitat area used for seaweeds: rocky reef The habitat area used for coral: coral The habitat area used for shells, ornamentals, sponges: coral plus rocky reef

3.4.0.17 Calculation

For each product: sustainability = 1- average(exposure, risk) Prod_score = sustainability*relative tonnes

Then take a weighted average of the Prod_score using the "weighting" file.

3.4.0.18 Notes on modifying the function

1. Several data layers are called that are not used: np_harvest_tonnes, np_harvest_usd, np_harvest_usd_relative
2. There are these notes that I'm not sure what they mean in function code: TODO: add smoothing a la PLoS 2013 manuscript TODO: move goal function code up to np_harvest_usd-peak-product-weight_year-max-%d.csv into ohiprep so layer ready already for calculating pressures & resilience
3. Minor recoding to get away from using reshape and plyr packages

3.4.0.19 *History of the Approach (lessons learned 2014)*

This goal model calculates overall status by weighting the status of sustainable harvest of each extracted marine product by its proportional value relative to other harvested products.

3.4.0.20 Model description

Global 2012: For the status of each product, we assessed the most recent harvest (in metric tons) per region relative to a fraction of the maximum value (in 2008 USD) ever achieved in that region. This was under the assumption that the maximum achieved at any point in time was likely the maximum possible, and that the sustainable maximum harvest was lower than that value, similarly to what is known about maximum fisheries harvests (Srinivasan et al., 2008). The status for each natural product category is calculated separately and then combined by weighting each category by the proportional value of that product relative to the total value of all products. Part of the status calculation for each product category is a measure of sustainability; the goal captures exposure, risk, and viability of harvesting the product.

Global 2013: This used the same approach as Global 2012. Data processing did change however; see below in Evolution of the Approach.

Brazil: This used the same approach as Global 2012.

US West Coast: The Natural Products score was not calculated because there are few data available on local-scale harvest and this is currently no longer pursued in any measurable quantities, and in the past had occurred mostly in the southern California region. Given this situation, the two options for how to include this goal in the assessment were to give the southern California region a zero (lowering the overall Index score), or to have the goal drop out completely of the assessment. The former option would assume there was demand for seaweed that was no longer met because the resource had been depleted, the latter assumes there is not enough demand for seaweed to make it commercially viable and so it is no longer harvested. We felt the latter was a more likely scenario.

3.4.0.21 Evolution of the approach

Global 2012: Natural products data were available for coral, ornamental fish, fish oil, seaweeds and marine plants, shells, and sponges from the UN FAO. Using these data, we weighted each category by the sustainability of harvest. We did not have data for other key natural products such as wood from mangroves, and we excluded oils from mammals as they are widely seen as (currently) unsustainably harvested due to low mammal populations. Mammal oils represented a small (~<2%) and decreasing amount of total oil harvest each year (since 1993 it has been well below 1%), although for some regions it remains a significant percent of total oil harvested.

Global 2013: We used the same data and basic approach as for Global 2012, but developed several methods to fill gaps in data that resulted from inconsistencies in the data reported to FAO. In particular, many regions only report either data on harvest or on the monetary value of each product for a given year, but not both. Since the score is computed as a weighted sum of individual product scores, if either the weight or the product score was 0, these mismatches in reporting would cause products to 'drop out' of the calculation of overall status, thus losing real data. The gap filling methods we developed estimated the US dollar value of harvested products from the tonnage reported; or the tonnage harvested based on a product's reported economic value.

Brazil: This used the same data and approach as for Global 2012.

US West Coast: Not included in US West Coast; this assessment therefore had only 9 goals that all had equal weighting.

3.4.0.22 The reference point

Global 2012: The reference point for Natural Products was based on the fisheries concept of maximum sustainable yield (MSY), applied to the extraction of natural products. MSY was assessed for each type of product quantified globally, and a temporal (historic benchmark) reference point for each product was defined as 35% below the maximum harvest that had been produced to date in the region being evaluated. The 35% buffer protects against the possibility that the maximum historical harvest was not sustainable. A high score indicates that a region's current sustainable rate of harvest is near to and not more than 65% of the historic maximum possible sustainable harvest achieved in that region.

Global 2013: Same approach as Global 2012.

Brazil: Same approach as Global 2012.

US West Coast: Not included in US West Coast.

3.4.0.23 Interpreting a score

A score of 100 would indicate that a region's natural product yield equals 65% of its historic maximum. A low score indicates that a region has the potential to improve sustainable harvests of natural products, either by eliminating overharvesting, increasing harvests that are too low, or reducing the pressures that decrease potential harvests. The more natural products extracted sustainably, the higher the score, provided that the harvest does not exceed the 65% precautionary level.

3.5 Carbon Storage

This goal focuses on the carbon stored in natural coastal ecosystems that absorb and sequester it in large amounts.

Coastal habitats play a significant role in the global storage of organic carbon because they have the highest per-area storage rates of any habitat. While the pelagic oceanic plays a large role in the sequestration of anthropogenic carbon, by acting as a large carbon sink, the mechanisms for open ocean carbon storage cannot be managed locally or regionally as there are no practical methods for intervention or manipulation. This goal instead focuses on the the status of coastal marine habitats with high carbon storage capacity. In addition to preventing storage of carbon in the future, the destruction of these marine habitats has been shown to release large quantities of carbon, damaging the overall health of coupled marine systems.

Ideally, to assess the amount of carbon stored in every coastal habitat, information would be available regarding coverage area and some measure of quality (for example, the density of mangrove coverage). Additionally, different weights would be assigned to the habitats based on their relative ability to store carbon (although exact values are poorly known, currently). The carbon storage model can incorporate such weights once they are available in a similar way to the methods developed for the coastal protection goal. The reference point for habitat-based goals will likely be temporal; this means that historic data are needed such that current habitat extent data can be compared to them.

3.5.0.24 Practical Considerations

3.5.0.25 ***Ideal Approach*** Ideally, to assess the amount of carbon stored in every coastal habitat, information would be available regarding coverage area and some measure of quality (for example, the density of mangrove coverage). Additionally, different weights would be assigned to the habitats based on their relative ability to store carbon (although exact values are currently poorly known). The carbon storage model can incorporate such weights once they are available in a similar way to the methods developed for the coastal protection goal. The reference point for habitat-based goals will likely be temporal; this means that historic data are needed such that current habitat and value data can be compared to them.

3.5.0.26 Recommendations for regional assessments The overall Carbon Storage model and approach should not change. Area and health quality of carbon-storing habitats are the two components that are important. For example, if you have area of mangrove coverage and density of the mangroves within that area, that is ideal. Ideally, you will have data on both area and some measure of quality, but this may not be the case.

Habitats included in this goal should store carbon for 100 years or more, not temporarily store it only to be quickly cycled back into the system. The Global 2012 assessment focuses on three ecosystems — mangroves, tidal marshes and seagrasses — for their ability to store and sequester carbon in their plants and soils. When destroyed or degraded, these ecosystems not only stop sequestering carbon but can start to release it, and can emit carbon for centuries and contribute to climate change. Though they form less than 2% of the ocean's surface, coastal ecosystems contribute more to long-term carbon storage and sequestration in sediments than any other ocean ecosystem. Ideally, we would also include a weighting factor that penalizes more the loss of habitats with higher carbon storage capabilities (or rewards more their restoration), but the science on this topic is still under development and this value depends on many factors that can vary, even within the same habitat type, based on the morphology of the sites.

Because they store carbon for less than 100 years, seaweeds and corals are not included in the carbon storage goal. While the pelagic oceanic carbon sink (phytoplankton) plays a large role in the sequestration of anthropogenic carbon, the pelagic ocean mechanisms are not amenable to local or regional management intervention. Phytoplankton contribute to carbon fixation when they die and sink to the sea bottom at sufficient depth, because it is effectively out of circulation. However, if those phytoplankton are eaten, the carbon is cycled back into the system and not sequestered. Something that could potentially be included in the carbon storage goal is mollusc shells, if they are added to a landfill and not recycled in the sea. So if information on mariculture production and waste disposal are available, this could be an interesting addition to carbon storage at a regional scale.

3.5.0.27 ***History of the Approach (lessons learned 2014)*** We refer to this goal as Carbon Storage but intend its meaning to include sequestration. Although ocean water itself can store carbon, increasing its carbon content has acidification as a side effect, with negative consequences for marine life. Our focus here is on coastal habitats, so-called "Blue Carbon", because they have large potential to store carbon without causing acidification, and, contrary to open oceans, they provide a carbon storage service that can be affected by human actions such as conservation, and restoration efforts. Highly productive coastal wetland ecosystems (e.g., mangroves, salt marshes, seagrass beds) have substantially larger areal carbon burial rates than terrestrial forests.

In basic terms, the plants take up carbon dioxide (CO) and store it in organic form within their tissues. Leaves and detritus that fall to the bottom and become covered with sediment retain those organic compounds for centuries or millennia if undisturbed. Natural (storms) or human (development) disturbance exposes this buried material to oxygen with the result that CO , the primary heat-trapping gas in the Earth's atmosphere, is released.

3.5.0.28 Model description Global 2012: The status of Carbon Storage is measured as a function of its current 'condition' relative to a reference condition and a variable that weights the relative contribution of each habitat type to total carbon storage (measured as the amount of area each habitat covers relative to the total area covered by all three habitats given the available data). In Global 2012, the coastal ecosystems assessed were: seagrasses, tidal marshes and mangroves.

Global 2013: Same as in Global 2012. Improvements in data processing are outlined below in Evolution of the Approach.

Brazil: Same as in Global 2012.

US West Coast: We used reconstructions of historic extents compared to current habitat coverage to set more ambitious targets. However, the historical reconstructions did not include information on habitat health so only extent was used in this assessment.

3.5.0.29 Evolution of the approach **Global 2012:** We focused on three coastal habitats known to provide meaningful amounts of carbon storage: mangroves, seagrasses, and salt marshes. For mangroves, we included the whole extent of the coastal forests, including the parts on land or in river deltas, since these too provide significant additional amounts of carbon storage.

Global 2013: Mangrove data used in the goal model were processed differently than described in Global 2012: data now include 1km inland in addition to 1km offshore.

Brazil: The same approach was used as in Global 2012, with local data used as available.

US West Coast: Only two out of the three habitats considered in the global analysis were included here: salt marshes and seagrass beds. Mangroves are not found in the US West Coast and are not included in this assessment.

3.5.0.30 The reference point **Global 2012:** Reference conditions were set as the current condition or area of coastal plant habitat coverage relative to that in ~1980. This is not a very ambitious reference point, but the best that the data would allow.

Global 2013: Same as Global 2012.

Brazil: The reference condition was determined specifically for each habitat type. For salt marshes the reference year is 1975. For mangroves, we knew the current (2010) extent per state, but only had a total country extent for the reference year (1980). We apportioned the total reported mangrove extent for Brazil in 1980 by state using a linear regression model that estimates the percent of mangrove loss per state. Data to assess current and reference condition for seagrasses did not meet minimum data requirements: they were available only for three sites in Brazil within the time period 2002-2010 (no data for a reference condition). For this reason, we used available data from adjacent EEZs (countries in the South Atlantic) and used georegional averages as current condition and reference condition values for Brazil. A linear model was fitted to the data for all countries, and the mean of predicted values for 1979-1981 was used as the reference condition, and the mean of predicted values of the three most recent years (2008, 2009, 2010) was used as the current condition.

US West Coast: Reliable, comprehensive habitat extent data prior to the 1990s are unavailable for most coastal regions within the U.S. Estimates of habitat loss since European settlement have been extrapolated in some regions for some habitats. However, while the habitat extent from the 1990s would represent a very un-ambitious target, a pre-industrialized reference point for habitat extent is considered an unrealistic goal under current conditions. To establish our temporal reference points we instead set our reference uniquely for each habitat, as a percentage of pre-industrialized habitat coverage for salt marshes, as habitat extent between the 1950s and 1960s for sand dunes, or utilized pressures on habitats as a proxy of habitat condition for seagrasses and soft bottom habitats.

3.5.0.31 Interpreting a score A score of 100 would indicate that the percent cover (and health, when measured) of each habitat had not changed since the date set as reference point (the 1980s or pre-industrial coverage, depending on the assessment used).

3.6 Coastal Protection

This goal captures the condition and extent of habitats that protect the coasts against storm waves and flooding. It measures the area they currently cover relative to the area they covered in the recent past.

Many habitats, including coral reefs, mangroves, seagrasses, salt marshes, and sea ice act, as natural buffers against incoming waves. By protecting against storm damage, flooding, and erosion, these living habitats keep people safe and can help mitigate economic loss of personal and public property, cultural landmarks, and natural resources. This goal assesses the amount of protection provided by marine and coastal habitats by measuring the area they cover now relative to the area they covered in the recent past.

Ideally, data for all habitats within regions of a study area would be available, as well as information on the value of the land and the vulnerability of inhabitants being protected by these habitats. This requires data for habitat type at high spatial resolution as well as a measure of the value of what is protected by the habitats. The reference point for habitat-based goals will likely be a temporal baseline; this means that historic data are needed such that current habitat and value data can be compared to them.

3.6.0.32 Practical Considerations

3.6.0.33 ***Ideal Approach*** Ideally, data for all habitats within a region would be available, as well as information on the value of the land and the vulnerability of inhabitants being protected by these habitats. This requires data for habitat type at high spatial resolution as well as a measure of the value of what is protected by the habitats. The reference point for habitat-based goals will likely be a temporal baseline; this means that historic data are needed such that current habitat and value data can be compared to them.

3.6.0.34 Recommendations for regional assessments This goal model aims to assess the amount of protection provided by marine and coastal habitats against flooding and erosion to coastal areas that people value, both inhabited (homes and other structures) and uninhabited (parks, special places, etc.). At local and regional scales data may exist on all these variables at a high enough resolution to map and calculate exactly which habitats are providing how much protection to which coastal areas. In addition, one might want to know the level of vulnerability of the different coastal communities (e.g. ability to evacuate, fragility of constructions, economic ability to reconstruct in case of damage, etc.), so as to prioritize protection of certain locations. Physical properties may be available in regional studies, allowing for more a detailed understanding of the protective ability, and likelihood of exposure for each habitat type in different portions of the coastline. We did not include an assessment of the protection afforded by man-made structures, such as jetties and seawalls, because these structures cannot be preserved without maintenance, may have other negative side effects (e.g. alter sedimentation rates causing erosion in new locations), thus they do not constitute long-term sustainable services. Model description

3.6.0.35 ***History of the Approach (lessons learned 2014)*** **Global 2012:** The status of this goal was calculated to be a function of the amount and/or condition (depending on data availability) of marine habitat(s) relative to their reference states and the ranked protective ability of each habitat type. Rank weights for the protective ability of each habitat come from previous work that ranks mangroves, corals and sea ice as 4, salt marshes as 3, and seagrasses as 1 (higher values are better).

Global 2013: Same as Global 2012.

Brazil: Same goal model as Global 2012, using local data.

US West Coast: Same as Global 2012, with more ambitious reference points for target habitat coverage.

3.6.0.36 Evolution of the approach **Global 2012:** At global scales, fine-scale habitat data do not exist and so we focused on EEZ-scale assessments, even though this scale does not allow one to account for the spatial configuration of habitats relative to coastal areas and the vulnerability of human coastal communities. Consequently, we assumed that all coastal areas have equal value and equal vulnerability and assessed the total area and condition of key habitats within each EEZ (without regard to their precise location). The habitats that provide protection to coastal areas from inundation and erosion and for which we have global data include mangroves, coral reefs, seagrasses, salt marshes, and sea ice.

Global 2013: Same as Global 2012.

Brazil: Area was measured for each coastal state as the 12 nmi jurisdiction boundary for each habitat type. For mangroves we focused only on the most coastal portion of mangrove forests as they are the main source of coastal protection. For seagrasses we used the total reported extent of seagrasses in Brazil divided by the coastal area of each state. For coral reefs we calculated the extent per coastal waters of each state using maps of coral reef distribution. The salt marsh extents for Santa Catarina and Rio Grande do Sul states are from national statistics.

US West Coast: In the U.S. west coast we measured the role of salt marshes, seagrasses, and sand dunes as these habitats provide the most significant and measurable amount of coastal protection and had data available to include.

3.6.0.37 The reference point **Global 2012:** The reference point for Coastal Protection compares the current extent and condition of five key habitats that protect coastlines (mangrove forests, seagrass meadows, salt marshes, tropical coral reefs, and sea ice) from flooding and erosion relative to their condition in the early 1980's.

Global 2013: Same as Global 2012.

Brazil: To calculate the reference state for coral reef status within Brazil we lacked a minimum of two data points within the time period 1980-1995 (which was considered the acceptable range to use as "reference" years). We therefore estimated the status as the averages of scores from 24 countries within the Caribbean ecoregion that had sufficient coral data. For each of those countries, we fitted a linear model to the data available, pooled across all sampled sites, and we defined the 'current' condition (health) as the mean of the predicted values for 2008-2010, and the reference condition as the mean of the predicted values for 1985-1987.

US West Coast: Reliable, comprehensive habitat extent data prior to the 1990s are unavailable for most coastal regions within the U.S. Estimates of habitat loss since European settlement have been extrapolated in some regions for some habitats. However, while the habitat extent from the 1990s would represent a very un-ambitious target, a pre-industrialized reference point for habitat extent is considered an unrealistic goal under current conditions. To establish our temporal reference points we instead set our reference uniquely for each habitat, as a percentage of pre-industrialized habitat coverage for salt marshes, as habitat extent between the 1950s and 1960s for sand dunes, or utilized pressures on habitats as a proxy of habitat condition for seagrasses and soft bottom habitats.

3.6.0.38 Interpreting a score A score of 100 would indicate that these habitats are all still intact or have been restored to the reference condition (i.e. their extent during the early 1980's if using Global 2012, or 50% of their extent for some of the habitats in US West Coast, etc.). Any score below 100 indicates that these habitats have declined in coverage or in health since then, with lower scores indicating more significant declines, and stronger penalties for declines in habitats with high protection ability (e.g. mangroves in Global 2012).

3.7 Coastal Livelihoods and Economies

This goal focuses on avoiding the loss of ocean-dependent livelihoods and productive coastal economies while maximizing livelihood quality. We measure the status of this goal through two sub-goals: **Livelihoods** (jobs and wages) and **Economies** (revenues). The two halves of this goal are tracked separately because the number and quality of jobs and the amount of revenue produced are both of considerable interest to stakeholders and governments, and could show very different patterns, such as the case when high revenue sectors do not necessarily provide large employment opportunities. The goal aims to maintain the number of coastal and ocean-dependent livelihoods (jobs) in a region, and maintain productive coastal economies (revenues), while also maximizing livelihood quality (represented by relative wages).

- #### 3.7.1 Livelihoods

  This sub-goal includes two equally important sub-components, the number of jobs, which is a proxy for livelihood quantity, and the per capita average annual wages, which is a proxy for job quality.

  This sub-goal evaluates the benefits people obtain from the oceans in the form of jobs and wages. Some relevant sectors include tourism, commercial fishing, marine mammal watching, and working at ports and harbors, among others. Jobs and wages produced from marine-related industries are clearly of huge value to many people, even those who do not directly participate in the industries but value community identity, tax revenue, and indirect economic and social impacts of a stable coastal economy.

  Ideally, this goal would capture all marine sectors that supply jobs and wages to coastal communities, incorporating information on the sustainability of different sectors and also working conditions and job satisfaction/identity. The jobs and revenue produced from marine-related industries directly benefit those who are employed, but also those that gain substantial indirect value from community identity, tax revenue, and other related economic and social impacts of a stable coastal economy. Capturing the indirect as well as direct benefits from jobs, wages and revenue from coastal communities and beyond is best; where data do not exist, multipliers derived from the literature can be incorporated into jobs to attempt to capture this. The reference point in this sub-goal will likely be set as a moving window temporal approach or a spatial comparison.

- #### 3.7.2 Economies

  This sub-goal captures the economic value associated with marine industries. This is done using revenue from marine sectors as a proxy.

  The economies sub-goal evaluates the revenue generated from marine-based industries. Strong coastal economies are something that people value, and this can be reflected by the GDP generated by these coastal regions both directly and indirectly.

  Ideally, economic data would be collected coastally, and traced from sectors both directly and indirectly related to marine industries. When these data are not available it is possible to use revenue data at a larger scale and adapt them to a coastal area based on population distribution. The reference point in this sub-goal will likely be set as a moving window temporal approach.

3.7.3 Practical Considerations

3.7.3.1 Recommendations for regional assessments There are several big decisions to consider when addressing the livelihoods and economies goal. The first is how to weight them when they are combined. In our assessments, the livelihoods and economies sub-goals are equally weighted when they are combined; it is possible to weight them differently. Another important choice is the reference year that is compared with the current status of livelihoods and economies. We chose a 5-year window because it is intended to capture short-term changes in trajectory, but, in regional assessments, there is the opportunity to study the behavior of the time-series with greater detail and, for example, establish a different time-period that reflects observed cycles, or even process the data to eliminate the “noise” from temporary fluctuations and capture more persistent trends.

3.7.3.2 ***History of the Approach (lessons learned 2014)***

The aim is to maintain (avoid the loss of) coastal and ocean-dependent livelihoods (i.e., jobs) and productive coastal economies (i.e., revenues), while also maximizing livelihood quality (relative wages). It does not attempt to capture any aspects of job identity (i.e. the reputation, desirability or other social or cultural perspectives associated with different jobs), although one can examine the component parts that make up this goal to evaluate individual sectors and infer implications for job identity.

3.7.4 LIVELIHOODS

3.7.4.1 Practical Considerations

3.7.4.2 ***Ideal Approach***

Ideally, this goal would capture all marine sectors that supply jobs and wages to coastal communities, incorporating information on the sustainability of different sectors and also working conditions and job satisfaction/identity. The jobs and revenue produced from marine-related industries directly benefit those who are employed, but also those that gain substantial indirect value from community identity, tax revenue, and other related economic and social impacts of a stable coastal economy. Capturing the indirect as well as direct benefits from jobs, wages and revenue from coastal communities and beyond is best; where data do not exist, multipliers derived from the literature can be incorporated into jobs to attempt to capture this. The reference point in this sub-goal will likely be set as a moving window temporal approach and/or a spatial comparison.

The Livelihoods sub-goal includes two equally important sub-components, the number of jobs, which is a proxy for livelihood quantity, and the per capita average annual wages, which is a proxy for job quality.

3.7.4.3 Recommendations for regional assessments

Within the livelihoods sub-goal, there is also the possibility of weighting the two subcomponents unequally (in all three assessments these are weighted equally), for example if the number of jobs was considered more important than the wages rendered.

There is another important decision to be made: what is a marine-related sector? There are jobs that are directly connected to the marine environment (fishing, shipping, ports,) but also some that are connected indirectly (suppliers, supporting industries). The use of multipliers in attempts to capture the indirect revenue generated by jobs more indirectly associated to marine sectors is important to include if possible; this is a well-established method in economics (see Evolution of the Approach, below). In terms of reference points: in the livelihoods sub-goal, jobs had a moving target temporal comparison and wages had a spatial comparison. Comparing the number of jobs across different places would require at the very least adjusting values by the size of the workforce in each location. We highly recommend keeping the reference point for jobs as a temporal comparison, and only using a spatial comparison for wages (adjusted by purchasing power).

3.7.4.4 ***History of the Approach (lessons learned 2014)***

3.7.4.5 Model description

Global 2012: This sub-goal is measured as the number of direct and indirect jobs across sectors within a region plus the average purchasing power parity (PPP)-adjusted wages within each sector. Jobs are summed across sectors and measured at current and reference time points. Wages are averaged across sectors within each region and the reference value is taken from the region with the highest average wages across all sectors.

Global 2013: Based on Global 2012, with some simplifications: Since many of the values were not available in 2010, older wages data were divided by the inflation conversion factor for 2010 so that wage data across years would be comparable in 2010 US dollars. These data were also multiplied by the purchasing power parity-adjusted per capita GDP (PPPpcGDP). Jobs data were adjusted by dividing by total number of people employed for the corresponding year: (1 – percent unemployment) * total labor force. This factor ensures that any changes detected are strictly due to marine-related dynamics and not driven by national macroeconomic events across all sectors, marine and not. One of the adjustment terms previously used was considered redundant and removed: an additional factor had previously been used to modify the wages data, obtained from the International Labour Organization (ILO).

Brazil: Same as Global 2012.

US West Coast: This goal follows the same model as in Global 2012, but using local data with a slightly different list of sectors. Data came from the National Ocean Economics Program (NOEP); sectors include: living resources, tourism and recreation, shipping and transport, marine related construction, and ship and boat building/repair. For each of these sub-components we use sector-specific multipliers derived from the NOEP data so that we assess both direct and indirect effects. We recognize that sectors and economic activity within a region can be influenced by activities outside the region (e.g., fish caught in Alaska could be brought to Washington for processing, or vice-versa), thus leading to an over or under estimate economic benefits derived from marine ecosystems within the study region. As with any ecosystem study, defining boundaries for the ecosystem is an artificial operation, and linkages with external elements necessarily exist but are challenging to account for.

3.7.4.6 Evolution of the approach **Global 2012:** We assumed that sector-specific job and revenue multipliers are static and globally consistent, but distinct for developed versus developing regions (when such information was available), because we do not have data to resolve temporal or regional differences. For all other sectors where the data sources only provided direct jobs or direct revenue, we used sector- and development status-specific multipliers derived from the literature to estimate total job or revenue impacts. We did not apply multiplier values to wages since the cascading effects of earned income are more contentious. To account for broader economic forces that may affect jobs independent of changes in ocean health (e.g., a global recession), we adjusted (as noted above) relative values for the number of jobs by changes in national employment rates.

While job identity has social and cultural value, there are not adequate data to track individual workers and assess their job satisfaction on a global scale. Also because of data constraints, this goal does not provide more credit for sectors or economic activities that are more ecologically sustainable.

Global 2013: Same as Global 2012 except for a few simplifications in terms of multipliers.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.7.4.7 The reference point **Global 2012:** In the livelihoods sub-goal, jobs had a moving target temporal comparison and wages had a spatial comparison. The reference point for jobs (and for the economies sub-goal) is a moving baseline because there is no established target for number of jobs (and setting a specific target number of jobs would be completely arbitrary). In these cases it is important to compare the same place to itself in the past, and not to compare it to a different place. Therefore, the objective of the jobs component is actually no loss of jobs. In addition, we want to ensure that we are detecting changes that are specific to marine-related sectors. Jobs must keep pace with growth in employment rates or sustain losses no greater than national increases in unemployment rates. For wages we assumed the target value for average annual wages is the highest value observed across all reporting units.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.7.4.8 Interpreting a score: A score of 100 would indicate that the number of marine jobs had not reduced relative to that number five years previous, and that the wages in the area were the highest anywhere.

3.7.5 ECONOMIES

3.7.5.1 Practical Considerations

3.7.5.2 ***Ideal Approach*** Ideally, economic data would be collected coastally, and traced from sectors both directly and indirectly related to marine industries. When these data are not available it is possible to use revenue data at a larger scale and adapt them to a coastal area based on population distribution. The reference point in this sub-goal will likely be set as a moving window temporal approach.

History of the Approach (lessons learned 2014)

Economies: The economies sub-goal is composed of a single component, revenue.

3.7.5.3 Recommendations for regional assessments In the economies sub-goal, revenue had a moving target temporal comparison; we highly recommend that this remains a temporal comparison so that a specific place is compared to its performance in the past and not to anywhere else. Model description

Global 2012: This sub-goal is captured as the total adjusted revenue generated directly and indirectly from each sector (measured in 2010 USD), at current and reference time points.

Global 2013: Same as Global 2012, with a few simplifications: Revenue data were adjusted by dividing by GDP per region (reported in 2013 USD; data from the World Bank).

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.7.5.4 Evolution of the approach Global 2012: We assumed that sector-specific job and revenue multipliers are static and globally consistent, but distinct for developed versus developing regions (when such information was available), because we do not have data to resolve temporal or regional differences. For all other sectors where the data sources only provided direct jobs or direct revenue, we used sector- and development status-specific multipliers derived from the literature to estimate total job or revenue impacts. We did not apply multiplier values to wages since the cascading effects of earned income are more contentious.

Global 2013: Same as Global 2012, although simplified where appropriate.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.7.5.5 The reference point Global 2012: In the economies sub-goal, revenue had a moving target temporal comparison. Because there is no absolute reference point for revenue, this sub-goal employs a moving baseline. We made a correction to revenue based on a region's GDP ("no loss and must keep pace with growth in GDP or can sustain losses comparable to national declines in GDP"). The current and reference years used for unemployment and GDP data were based on the average current year and average reference year across the sector data sources used for number of jobs and revenue, respectively.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.7.5.6 Interpreting a score A score of 100 would indicate that revenue has not decreased compared to its value five years previous.

3.8 Tourism and Recreation

This goal captures the value people have for experiencing and taking pleasure in coastal areas.

Tourism, travel, and recreation in coastal and ocean areas are major components of thriving coastal communities and a measure of how much people value ocean systems.

Ideally, information would be available on how the ocean is used for enjoyment by both local residents and tourists, thereby capturing the full value of touristic and recreational activities. Models will vary greatly depending on data available; there are many ways to potentially measure the delivery of this goal. The type of reference point used will depend on the data available.

3.8.0.7 What it does not measure **Tourism and Recreation** does not include the revenue or livelihoods that are generated by tourism and recreation; that is captured in the **Livelihoods and Economies** goal.

3.8.0.8 Practical Considerations

3.8.0.9 ***Ideal Approach*** Ideally, information would be available on how the ocean is used for enjoyment by both local residents and tourists, thereby capturing the full value of touristic and recreational activities. Models will vary greatly depending on data available: there are many ways to potentially measure the delivery of this goal. The type of reference point used will depend on the data available.

3.8.0.10 Recommendations for regional assessments This is an excellent example of having to create a model using data that are suboptimal for the goal's aim, but it also shows how flexible the OHI approach is to adapting models with improved data or approaches. If possible, using an approach like the US West Coast or Global 2013 is preferable than the approach used in Global 2012.

There are potentially dozens of variables that affect the number of people that engage in tourism and recreation within a region and where they go, including local and global economies, infrastructure to support the activities, promotion of particular locations, safety and security, political stability, and so on. Because we currently do not know which variables matter and to what degree, or have data for many of these variables, we instead assume that tourists distribute themselves within a region proportional to where local populations are, i.e. that populated areas get a greater proportion of the tourists. The reference point used will depend upon the types of data incorporated into the model.

3.8.0.11 ***History of the Approach (lessons learned 2014)*** This goal measures the value people have for experiencing and taking pleasure in coastal areas. Tourism and recreation in coastal areas is a major component of thriving coastal communities and a measure of how much people value ocean systems, i.e. by traveling to coastal and ocean areas, people express their preference for visiting these places. This goal is not about the revenue or livelihoods that are generated by tourism and recreation (that is captured in the livelihoods goal) but instead captures the value that people have for experiencing and enjoying coastal areas.

3.8.0.12 Model description **Global 2012:** Data on international arrivals were used as a proxy for the value of tourism and recreation in each region, as this was the most comprehensive data available on a global scale. Additionally, the length of each tourist's stay in a region was incorporated: we used tourist-days as the measure for this goal because some locations, especially remote ones, may receive fewer arrivals but tourists may stay for longer periods of time. We therefore multiplied the number of arrivals by the average length of stay in order to incorporate this information. Sustainability was incorporated by using the tourism competitiveness index (TTCI) from the World Economic Forum to capture the sustainability of the tourism industry. To account for different surface areas and number of inhabitants across regions, the tourist-day values were adjusted by local population size.

Global 2013: We calculated the proportion of direct employment in the tourism industry relative to total labor force. As in Global 2012, we used the tourism competitiveness index (TTCI) from the World Economic Forum to capture the socio-economic sustainability of the tourism industry.

Brazil: The model developed for Global 2012 was changed to use information on hotel employees for each coastal municipality in Brazil. Status was measured for each coastal state as the density of hotel jobs in coastal areas. We log-transformed coastal area under the assumption that density of hotel employees is not necessarily a measure of sustainable tourism, but that a balance likely exists between the density of tourists and the absolute number of tourists that a state receives (even if spread out over a larger area). Although the TTCI was included in the model as a measure of sustainability, this value is calculated at the national level, and was therefore applied equally to all states. Due to this, it has no effect on differences between regions within Brazil. The model could be improved if a state-specific index assessing sustainability of coastal tourism were available.

US West Coast: At this scale we were able to make use of detailed studies documenting the changes in participation in 19 different marine and coastal specific recreational activities over time. These data come from the National Survey on Recreation and the Environment (NSRE), which has been conducted 8 times nationally since 1960, with the most recent data available for coastal and marine specific activities from 2000. These observations were used to produce a predictive model that was employed to estimate participation rates in recent years, because the survey data were no longer being collected.

3.8.0.13 Evolution of the approach **Global 2012:** It is very difficult to have a quantitative measure of whether people are fully taking advantage of recreation opportunities offered by marine and coastal environments. We assumed that the amount of international arrivals (although this ignores domestic travel and recreation), however, could be informative of the desirability of a coastal location and that this must have some relation with the health of the system. We use a spatial comparison reference point that compares each region to the best performing regions. In order to compare different regions, we standardize by dividing the arrivals by the region's population.

Few non-economic indicators of tourism and recreation exist at the global scale, and thus the original approach in Global 2012 approximated this goal measuring the number of international tourists arriving by airline to coastal regions, accounting for their average length of stay, and adjusting by the region's population size. This approach was sub-optimal because it did not account for domestic tourism, which is a large part of tourism in many regions. Also, since we only had information about total arrivals, not just those of people who were intending to spend time on the coast, we standardized by dividing by the total population, not just the coastal inhabitants, which tended to penalize especially large regions with large stretches of inhabited inland areas such as Canada, Australia and the USA.

We log-transformed the status scores because of an extremely exponential distribution of scores driven by a few regions with much higher tourism rates relative to population size. Even after this transformation the distribution of scores remained strongly exponential and so we rescaled scores to the value of the 90th percentile region, which was 25% of the maximum score. The 17 regions above this score were all given status scores = 1.0.

Global 2013: We created a new model different from Global 2012 by using employment in the tourism sector as a reasonable proxy measure for the total number of people engaged in coastal tourism and recreation activities. Employment within this sector should respond dynamically to the number of people participating in tourist activities, based on the assumption that the number of hotel employees, travel agents and employees of other affiliated professions will increase or decrease with changing tourism demand within different regions.

Ideally there would be data available specifically for employment in coastal tourism industries, however the best data available at a global scale report total number of jobs, not just coastal jobs, within the travel and tourism industries. These data include jobs that are directly connected to the tourism and travel industry (i.e. for both leisure and business), including accommodation services, food and beverage services, retail trade, transportation services, and cultural, sports and recreational services, but exclude investment industries and suppliers. Unfortunately it was not possible to determine the proportion of jobs affiliated with strictly leisure travel. However, some (unknown) proportion of business travelers also enjoy the coast for leisure during their visit to coastal areas, such that we assumed all travel and tourism employment was related to tourism and recreation values. Additionally, it is true that not every tourist stays in a hotel and not everyone staying in a hotel is a tourist. Nevertheless, these data are of better quality and closer to what this goal is trying to capture than those used in Global 2012.

Brazil: The goal model for Brazil assumes that the majority of coastal hotels are located in proximity to the shoreline, and that the number of hotel employees is directly proportional to the volume of tourists an area receives. A report evaluating drivers of tourism in Brazil found a significant positive relationship between number of tourists and number of hotels; here we incorporate hotel employees which is likely a more sensitive metric, given that hotels can vary greatly in size and economic changes are likely to be reflected more quickly in number of jobs than number of hotel establishments.

US West Coast: For the tourism and recreation goal we developed an approach that took advantage of time series data on participation in a range of coastal and marine tourism and recreational activities. Participation rates more closely matched the intent of this goal and were a more robust proxy than international tourist arrivals data, i.e., the proxy used in Global 2012. We also changed the tourism and recreation reference point from spatial (used in the global analysis, where having values from >170 assessed regions made this reasonable) to temporal (given availability of time-series and limited scope for spatial comparisons).

3.8.0.14 The reference point **Global 2012:** Global 2012 used a spatial comparison reference point that compares each region to the best performing regions.

Global 2013: To determine the reference point, we identified the best scoring region across all years and rescaled all other regions across all years to that score (Bonaire; 2011, which was the most recent year of data). The high-scoring regions were outliers in the distribution of scores (the second best performing region scored 40 and the third scored 28); we therefore rescaled all scores to the 90th percentile score. All regions above this score received a status score of 100.

Brazil: The reference value used was the highest status value across all states over the time series, which was Rio de Janeiro in 2011.

US West Coast: This model employs a temporal reference point, comparing current status to the status in the year 2000.

3.8.0.15 Interpreting a score A score of 100 in US West Coast would indicate that tourism in a specific place has not declined compared to its value in the reference year. In other assessments this would indicate that a value was not lower than the region with the highest score.

3.9 Sense of Place

The sense of place goal aims to capture the aspects of coastal and marine systems that people value as part of their cultural identity and connectedness to the marine environment. This definition includes people living near the ocean and those who live far from it and still derive a sense of identity or value from knowing particular places or species exist. Since few groups, communities, or states have explicitly described the attributes of the coastal and ocean environments that have special cultural meaning, the Index assesses the conditions that reflect how well this goal is being delivered through two sub-goals, **Iconic Species** and **Lasting Special Places**. The overall **Sense of Place** goal is then the arithmetic mean of the two sub-goal scores.

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3.9.1 Iconic Species

This sub-goal describes the species that are important to a region: iconic species are defined as those that are relevant to local cultural identity through one or more of the following: 1) traditional activities such as fishing, hunting or commerce; 2) local ethnic or religious practices; 3) existence value; and 4) locally-recognized aesthetic value.

The intent of the iconic species sub-goal is to focus on those species widely perceived as iconic within a region, and iconic from a cultural or existence value. This is in contrast to an economic or extractive reason for valuing the species. Iconic species symbolize the cultural, spiritual, and aesthetic benefits that people hold for a region, often bringing intangible benefits to coastal communities and beyond.

Ideally, data would be available on all species that are important to coastal communities, and then a separate assessment would judge the condition of each of the populations. Because almost any species can be iconic to someone, defining which species are culturally iconic can be challenging; information can sometimes be found from local customs and experts, oral tradition, sociological or anthropological literature, journalism and regional assessments. The type of reference point used will depend on the data available.

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3.9.2 Lasting Special Places

This sub-goal captures the conservation status of geographic locations that hold significant aesthetic, spiritual, cultural, recreational, or existence value for people.

Well-maintained and protected lasting special places provide intangible but significant resources that help sustain and may also generate economic opportunities and help to sustain coastal communities, but those are captured in other goals.

Ideally, a list of all the places that people within a region consider special could be found or developed, along with an assessment of what percent of and how well those areas are protected. The type of reference point used will depend on the data available.

3.9.3 Practical Considerations

3.9.3.1 Recommendations for regional assessments: The sub-goals were weighted equally when combined to create a single goal score.The two sub-goals are averaged currently in the framework. But these could be combined with a weighted average, or even a different sub-goal instead of Sense of Place, perhaps one based on the extent to which spiritual or religious activities are able to access their special places. It is important to think creatively about how this goal can be tailored more effectively to a specific region.

3.9.4 ICONIC SPECIES

3.9.4.1 Practical Considerations

3.9.4.2 ***Ideal Approach*** Ideally, data would be available on all species that are important to coastal communities, and then a separate assessments would judge the condition of each of the populations. Because almost any species can be iconic to someone, defining which species are culturally iconic can be challenging; information can sometimes be found from local customs and experts, oral tradition, sociological or anthropological literature, journalism and regional assessments. The type of reference point used will depend on the data available.

3.9.4.3 Comparing SPP and ICO

General Issue: SPP and ICO use different models for the OHI eez analyses (but not for HS and Ant). We are exploring whether we should modify the SPP or ICO model.

ICO status is calculated by taking the average of the IUCN ratings for all the iconic species in the eez.

SPP status takes into account the IUCN score and the area that the species occupies (although the results are not exactly equivalent to an area weighted average). Specifically, the values are calculated at the spatial scale of the raster cells (which I believe is at 0.5 degree resolution). For each raster cell, the IUCN scores of the species are averaged to get a score. To get status, the raster cell scores within an EEZ are then averaged (after weighting for the area of the raster cell).

3.9.4.4 The SPP (cell-averaging) method of calculating status

The original logic was to represent the species present relative to the proportion of their range within a given EEZ. We may also have wanted to avoid penalizing a region too heavily if only a very small portion of the range came from a very threatened species. I think we were also worried about bad aqua maps data that could misallocate species into a country and having a big effect.

A disadvantage is that rare species (and those with contracting ranges) will have a relatively small influence on the score. Common species will, in most cases, drive the results.

An advantage is (actually a disadvantage of averaging species scores at the eez level): "The bigger an area, the more likely you are to find rare at risk species (the classic problem of species-area relationships or SARs) - so bigger countries would have lower diversity scores just as a function of their size but not actual poorer biodiversity. In regards to sampling effort, the number of rare species increases faster than the number of common species, so they would not even each other out."

3.9.4.5 Current plan

For now, we are going to calculate SPP using both methods and evaluate (or present both).

3.9.4.6 *History of the Approach (lessons learned 2014)*

Iconic species are those that are relevant to local cultural identity through a species' relationship to one or more of the following: 1) traditional activities such as fishing, hunting or commerce; 2) local ethnic or religious practices; 3) existence value; and 4) locally-recognized aesthetic value (e.g., touristic attractions/common subjects for art such as whales). Model description

Global 2012: Status of this sub-goal is the average extinction risk of iconic species, calculated as the weighted sum of the number of species in each threat category, where an increasing weight is assigned by level of extinction risk of the threat category. This formula penalizes the gravity and number of species endangered among those recognized as iconic. Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: To assess the status of these iconic species within the region we used the same methods outlined in Global 2012, but replaced the global IUCN risk assessments with regionally specific species assessments provided by NatureServe.

3.9.4.7 Evolution of the approach

Global 2012: To define the list of iconic species for each region, we compiled lists of region-specific iconic species combined with lists of globally-recognized iconic species to create the total list of iconic species per region (see 'Iconic species' in section 7). Species were drawn from the World Wildlife Fund's global and regional lists for Priority Species (especially important to people for their health, livelihoods, and/or culture) and Flagship Species ('charismatic' and/or well-known). Ultimately, almost any species can be iconic to someone, and so the intent with this goal was to focus on those species widely seen as iconic from a cultural or existence value (rather than for a livelihoods or extractive reason). Many lists exist for globally important, threatened, endemic, etc. species, but in all cases it is not clear if or to what extent these species represent culturally iconic species. The lists we used from World Wildlife Fund are the only source that included cultural reasons for listing iconic species but they only cover a few regions and by no means capture the rich diversity of species that are iconic for local regions, communities, religions, tribes or other groups elsewhere. Collecting data at those scales would be a very important advance forward.

Habitat-forming species are not included in this definition of iconic species, nor are species that are harvested solely for economic or utilitarian purposes (even though they may be iconic to a sector or individual).

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012, with regional data for the threat categories.

3.9.4.8 The reference point **Global 2012:** The reference point is to have the risk status of all assessed species as Least Concern, meaning that the species is at lowest risk of extinction. Species that either have not been assessed or are labeled as data deficient are not included in the calculation.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.9.4.9 Interpreting a score A score of 100 would indicate that all species are in the threat category equivalent to 'least concern'.

3.9.5 LASTING SPECIAL PLACES

3.9.5.1 Practical Considerations

3.9.5.2 *Ideal Approach* Ideally one would have (or develop) a list of all the places that people within a region consider special, and then assess what percent of and how well those areas are protected. The type of reference point used will depend on the data available.

3.9.5.3 *History of the Approach (lessons learned 2014)* This sub-goal focuses instead on those geographic locations that hold particular value for aesthetic, spiritual, cultural, recreational or existence reasons. The scores for this sub-goal are calculated based upon two assumptions: that all regions have roughly the same percentage of their coastal areas (outward to 3 nm and inland to 1 km from the shore) that qualify as lasting special places, and that the regions with the most protected areas are the closest to achieving their region-specific target.

3.9.5.4 Model description **Global 2012:** The status of this sub-goal is calculated by combining the percent of coastal waters that are coastal marine protected areas and the percent of coastline that is protected. Both sea and land components are compared to a target (reference point) of 30% protection.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012. Evolution of the approach:

Global 2012: This sub-goal is particularly hard to quantify, because there are no lists of marine places protected especially for their cultural, spiritual, aesthetic or related intangible values. Ideally one would survey every community around the world to determine the top list of such special places, and then assess how those locations are faring relative to a desired state (e.g., protected or well managed), but in the absence of such lists we assume areas that are protected for other reasons (e.g. MPAs, reserves, historical areas, World

Heritage sites, etc.) represent these special places (i.e. the effort to protect them suggests they are important places) and that in each region there are enough special places to cover at least 30% of the coastal strip. Clearly this is an imperfect assumption, but in many cases it was true so that it did not prove unrealistic.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: This approach also focuses on the protection status of all marine and coastal areas as was done in the global assessment, under the assumption that efforts to protect places suggest that they are significant to people. We recognize that for some individuals, placing regulations on an area to protect it may prevent them from the very activities that made those places special to them in the first place, such that higher protection may not represent a healthier state in their view. However, we use this approach here because data exist to calculate it and because, although imperfect, it does convey some information about lasting special places. If a place is special and appropriate regulations/protection are placed on that location (for example, limited access, restrictions or limits on uses such as fishing, etc.), we feel that this ensures long-term sustainability of a place people care about.

3.9.5.5 The reference point **Global 2012:** Using lists of protected areas as the catalogue of special places then creates the problem of determining a reference condition. We do not know how many special places have yet to be protected, and so we end up having all identified special places also being protected. To solve this problem we make two important assumptions. First, we assume that all regions have roughly the same percentage of their coastal waters and coastline that could qualify as lasting special places. In other words, they all have the same reference target (as a percentage of the total area). Second, we assume that protecting 30% of the coastal area is a target that allows protecting enough lasting special places to achieve the goal.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012.

3.9.5.6 Interpreting a score A score of 100 would indicate that 30% of the waters and land immediately adjacent to the coast is protected.

3.10 Clean Waters

This goal captures the degree to which waters are polluted by natural and human-made causes.

People enjoy the presence of unpolluted estuarine, coastal, and marine waters for their aesthetic value and because they help avoid detrimental health effects to people or the marine life on which they depend. Many things can be responsible for negatively affecting clean waters, including sewage pollution (fecal coliform, viruses, parasites), nutrient runoff (eutrophication, algal blooms), chemical pollution (oil spills), and marine debris (floating trash). Combining the scores for these pollutants with a geometric mean in the goal model ensures that just one of the pollutants can drive the score, with the philosophy that if one of the pollutants is greatly impacting the system, how the others are affecting the system is less critical because there is already great impact.

Ideally, data would be available and combined from many different categories of marine pollution to best capture the factors that can cause waters to become unsuitable for recreation or other purposes. The type of reference point used will depend on the data available; a functional relationship would be best for setting limits to uses.

3.10.0.7 Practical Considerations

3.10.0.8 ***Ideal Approach*** Ideally, data would be available and combined from many different categories of marine pollution to best capture the factors that can cause waters to become unsuitable for recreation or other purposes. The type of reference point used will depend on the data available; a functional relationship would be best for setting limits to uses.

3.10.0.9 ***History of the Approach (lessons learned 2014)*** Clean Waters: This goal captures the degree to which waters are polluted by eutrophication (excess nutrients mostly from fertilizers and sewage), trash, pathogens and chemicals. People value marine waters that are free of pollution and debris for aesthetic and health reasons. Contamination of waters comes from oil spills, chemicals, eutrophication and algal blooms, disease pathogens (e.g., fecal coliform, viruses, and parasites from sewage outflow) and floating trash. People are sensitive to these phenomena occurring in areas that they access for recreation or other purposes as well as for simply knowing that clean waters exist. This goal scores highest when the contamination level is zero.

3.10.0.10 Recommendations for regional assessments We recommend that pollutants are combined with a geometric mean, as done in the assessments presented, as this guarantees that if any one of the components scores very poorly, the higher scores from other components can't make up for it.

Due to data constraints, the models described below mostly used information on pollutant inputs from point sources. If in-situ measurements of water and biological uptake from organisms are available, these types of information should be preferred. Particularly, information on eutrophication anomalies, anoxic regions and toxic blooms, would be preferable to the nutrient inputs proxy used in previous assessments. We were not able to assess specific toxic chemicals at the global scale; however regional case studies often will have data available for the quantities and toxicity of a range of chemicals put into watersheds and coastal waters. In addition, where possible and relevant, we recommend including additional component that could not be covered in the models presented here due to data constraints, such as altered sedimentation/turbidity.

3.10.0.11 Model description **Global 2012:** We aggregated various measures of pollution into four components that comprise the Clean Waters goal: eutrophication (nutrients), chemicals, pathogens and marine debris. This decision was meant to represent a comprehensive list of the contamination categories that are commonly considered in assessments of coastal clean waters and for which we could obtain datasets. The status of this goal is calculated as the geometric mean of four components: the number of people without access to sanitation (i.e. coastal population density times % without access to enhanced sanitation), 1 − (nutrient input), 1 − (chemical input), and 1 − (marine debris input).

We used a geometric mean, as is commonly done for water quality indices, because a very bad score for any one sub-component would pollute the waters sufficiently to make people feel the waters were 'too dirty' to enjoy for recreational or aesthetic purposes (e.g. a large oil spill trumps any other measure of pollution).

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012, with regional instead of global data.

3.10.0.12 Evolution of the approach **Global 2012:** Because of limited data availability for chemical pollution, we measured the chemicals component as the average of land-based organic pollution, land-based inorganic pollution and ocean-based pollution from commercial shipping and ports. We did not have global data for oil spills and so could not include oil pollution (although we did include pollution from ships), but in future assessments where such data exist it would be included in chemical pollution as well. In all four cases, the status of these components is the inverse of their intensity (i.e., high input produces a low status).

Human-derived pathogens reach coastal waters primarily from sewage discharge or direct human defecation. Since we did not have access to a global database of in situ measurements of pathogen levels, we used a proxy measure for the status of pathogen pollution, namely the number of people in coastal areas without access to improved sanitation facilities. The underlying assumption is that locations with a low percentage of people with access to improved facilities will likely have higher levels of coastal water contamination from human pathogens. To estimate this pathogen intensity, we multiplied average population density within the 50km of land adjacent to coasts by the percentage of the population without access to improved sanitation. This allows regions with low coastal population densities and low access to improved sanitation to score better than high population regions with better access if the absolute number of people without access is lower in the small region.

Global 2013: Same as Global 2012.

Brazil: Data used to model the components for eutrophication (nutrients) and chemicals was the same as in Global 2012. In short, nutrient pollution is estimated using a model of land-based nitrogen inputs and chemical pollution is measure via three global datasets on pollution from agricultural pesticide use, runoff from impervious surfaces, and commercial shipping and ports. Data to characterize pathogen and marine debris pollution were developed using state-level data for Brazil. We used the same approach to model both components, namely the number of people in coastal areas without access to sewage treatment (pathogens), and without access to improved solid waste management of three types (marine debris).

US West Coast: Same as Global 2012, with regional instead of global data.

3.10.0.13 The reference point **Global 2012:** This goal scores highest when the contamination level is zero.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: The reference point for pathogens was modified due to better data available. This was set as the number of days when beaches were closed to bathers because pathogen counts were higher than state standards.

3.10.0.14 Interpreting a score A score of 100 would indicate that the contamination level is zero.

3.11 Biodiversity

This goal captures the conservation status of marine species. Because the status of only a small portion of the world's species has been assessed, the condition of habitats is also calculated as proxy for the status of the many species that rely upon them. Thus, the condition of species and key habitats that support species richness and diversity is measured through two sub-goals: habitats and species. A simple average of these two sub-goal scores was used to obtain a single biodiversity goal score.

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3.11.1 Species

This sub-goal is conceptually equal to iconic species, but it includes all species that are assessed. The second difference is it also includes the amount of area where each species is present. So species that inhabit a greater area have a greater weight in the calculations than those with a smaller range.

This sub-goal aims to estimate how successfully the richness and variety of marine life is being maintained. People value the species that comprise marine biodiversity for their existence value as well as their contributions to resilient ecosystem structure and function. Biodiversity can also play a supporting role in food provision and sustainability generally, and is therefore also included in resilience dimensions of other public goals.

Ideally, data would be available on the number of species in each region of a study area, their habitat ranges, and assessments of their population or conservation status. The type of reference point used will depend on the data available.

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3.11.2 Habitats

This sub-goal measures the condition of habitats that are important for supporting a wide array of species diversity.

Because not all species have been assessed, this sub-goal measures some of the habitats that are particularly important in supporting large numbers of marine species. This sub-goal is conceptually similar to the carbon storage goal but includes all habitats with sufficient data, not just those that sequester carbon.

Ideally, information on the extent and condition of every single habitat type would be available. The reference point for habitat-based goals will likely be temporal; this means that historic data are needed such that current habitat and value data can be compared to historic data.

3.11.3 Practical Considerations

Note that SPP is the only goal with an upper and lower ref pt if you have great data on SPP, you don't need the HAB part of the BD goal.

3.11.3.1 ***History of the Approach (lessons learned 2014)*** People value biodiversity in particular for its existence value. The risk of species extinction generates great emotional and moral concern for many people. As such, this goal assesses the conservation status of species based on the best available global data through two sub-goals: Species and Habitats. Species were assessed because they are what one typically thinks of in relation to biodiversity. Because only a small proportion of marine species worldwide have been mapped and assessed, we also assessed Habitats as part of this goal, and considered them a proxy for condition of the broad suite of species that depend on them.

3.11.3.1.1 Recommendations for regional assessments If comprehensive species biodiversity data exist, these data can be used alone and the sub-goal of habitats can be removed (so that the entire goal is species biodiversity). However, the inventory of marine biodiversity may not often be sufficiently complete to permit that.

3.11.4 SPECIES

3.11.4.1 Practical Considerations

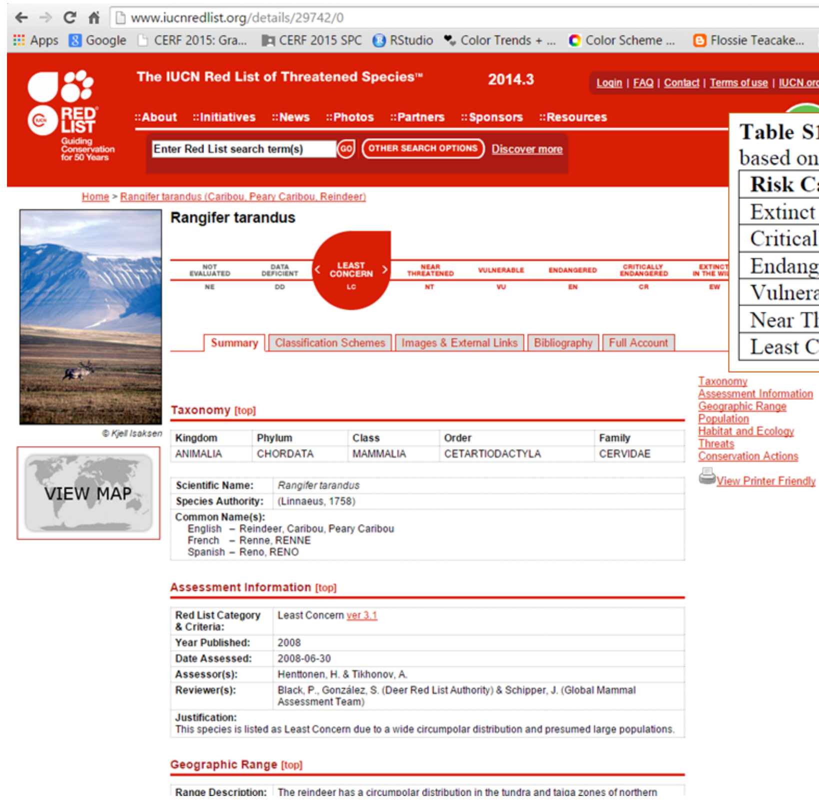
3.11.4.2 ***Ideal Approach*** Ideally, data would be available on the number of species, their habitat range, and assessments of their population or conservation status. The type of reference point used will depend on the data available.

that SPP is the only goal with an upper and lower ref pt if you have great data on SPP, you don't need the HAB part of the BD goal.

3.11.4.3 Preparing Data

3.11.4.3.1 SPP: Based on two primary types of data

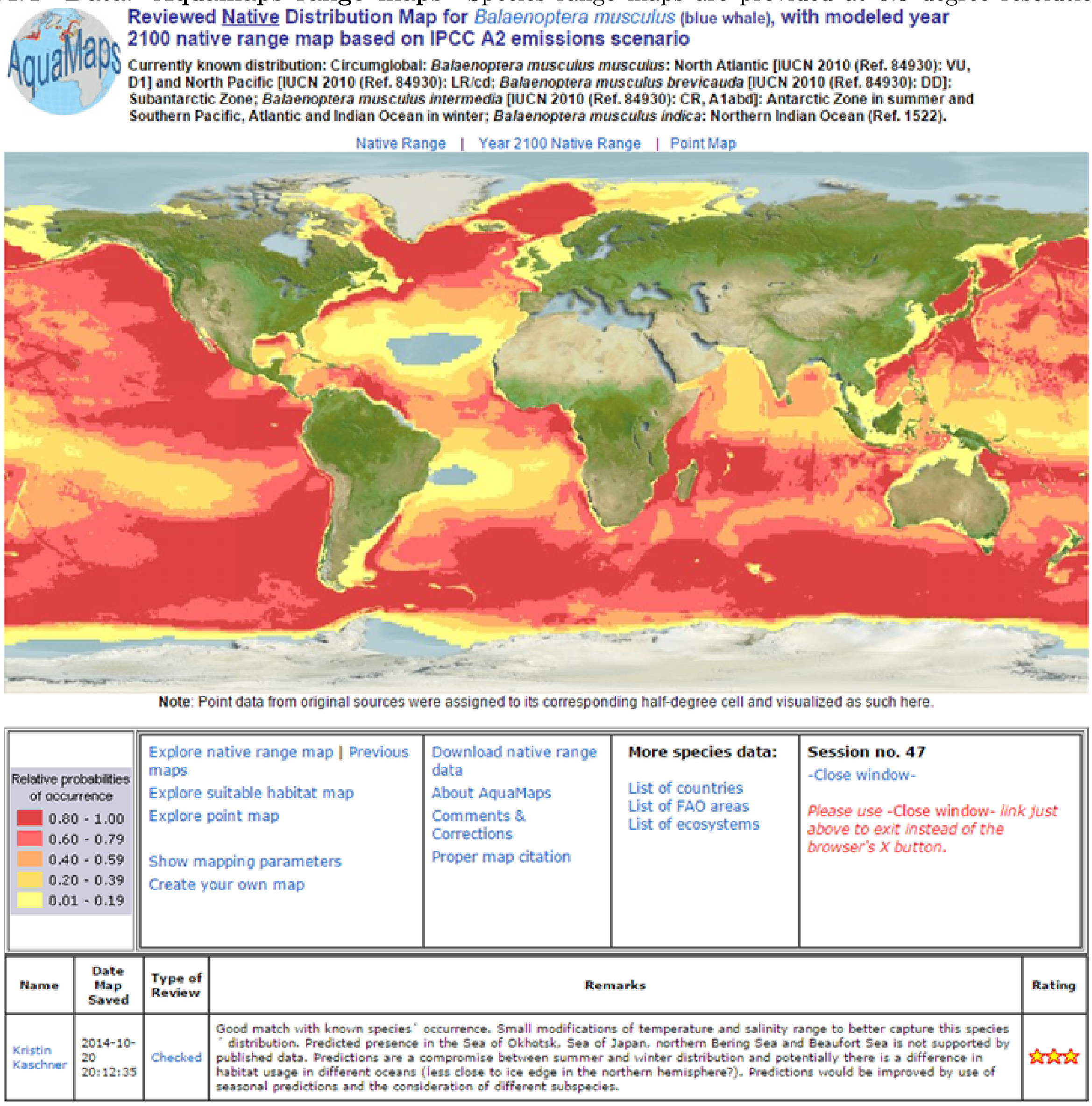
- Distribution of species (IUCN and aquamaps data)
- Extinction risk status (IUCN data)



3.11.4.3.2 Data: IUCN extinction risk status

(there are also range maps available from their website)

3.11.4.4 Data: Aquamaps range maps Species range maps are provided at 0.5 degree resolution:



3.11.4.5 Calculations (I am ignoring the area correction that must be done because 0.5 degree grid cells have different areas depending on latitude)

- STEP 1: Overlay all species distribution maps

- STEP 2: For each cell, average the risk status of each species (Risk status = 1 - IUCN Weight)
- STEP 3: For each cell, calculate: Condition = 1 - avg risk status

Then, calculate score based on a reference point of 0.75 (corresponds to an average of 75% of species are extinct, a level comparable to the five documented mass extinctions):

(Condition - 0.25) / 0.75 * 100

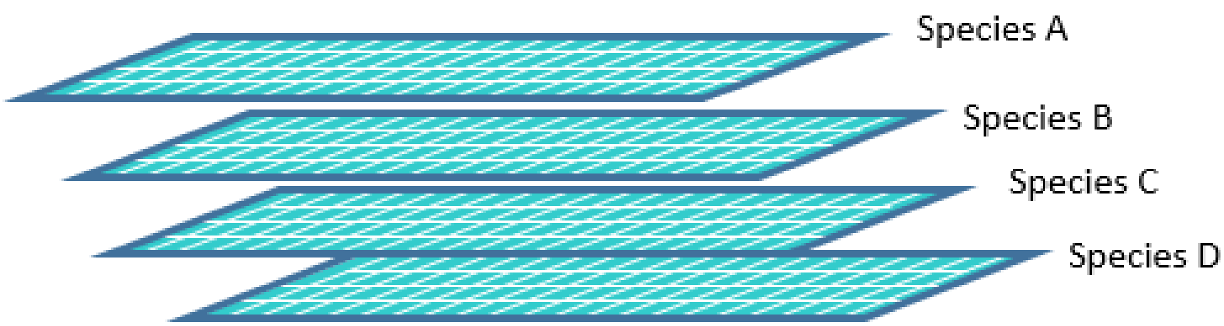


Figure 2: image

Condition	Score
1	1
0.9	0.87
0.75	0.66
0.5	0.33
0.25	0

Figure 3: image

- STEP 4: Summarize cell values by country boundaries.
- STEP 5: Calculate trend: Repeat steps 2-4, but instead of using the IUCN risk status, use the IUCN population trend for each species:

Increasing = 0.5 Stable = 0 Decreasing = -0.5

(This is different from how we calculate most trends where we do a linear model of status over the past 5 years).

3.11.4.6 Potential limitations

Score is driven primarily by common species because we are doing something close to area weighted average of the scores (although its not exactly equivalent to an area weighted average). Consequently, rare species that may have poor status scores do have much influence on the score.

Possible solution: Average the IUCN status of all species found in a region. This way rare and common species will have the same weight. This is how we have been calculating the scores for the iconic species subgoal (after subsetting the species data to include only iconics).

We will use both methods to calculate scores for OHI 2015.

3.11.4.7 Comparing SPP and ICO

General Issue: SPP and ICO use different models for the OHI eez analyses (but not for HS and Ant). We are exploring whether we should modify the SPP or ICO model.

ICO status is calculated by taking the average of the IUCN ratings for all the iconic species in the EEZ.

SPP status takes into account the IUCN score and the area that the species occupies (although the results are not exactly equivalent to an area weighted average). Specifically, the values are calculated at the spatial scale of the raster cells (which I believe is at 0.5 degree resolution). For each raster cell, the IUCN scores of the species are averaged to get a score. To get status, the raster cell scores within an EEZ are then averaged (after weighting for the area of the raster cell).

3.11.4.8 The SPP (cell-averaging) method of calculating status

The original logic was to represent the species present relative to the proportion of their range within a given EEZ. We may also have wanted to avoid penalizing a region too heavily if only a very small portion of the range came from a very threatened species. I think we were also worried about bad aqua maps data that could misallocate species into a country and having a big effect.

A disadvantage is that rare species (and those with contracting ranges) will have a relatively small influence on the score. Common species will, in most cases, drive the results.

An advantage is (actually a disadvantage of averaging species scores at the EEZ level): "The bigger an area, the more likely you are to find rare at risk species (the classic problem of species-area relationships or SARs) - so bigger countries would have lower diversity scores just as a function of their size but not actual poorer biodiversity. In regards to sampling effort, the number of rare species increases faster than the number of common species, so they would not even each other out."

3.11.4.9 Current plan

For now, we are going to calculate SPP using both methods and evaluate (or present both).

3.11.4.10 *History of the Approach (lessons learned 2014)*

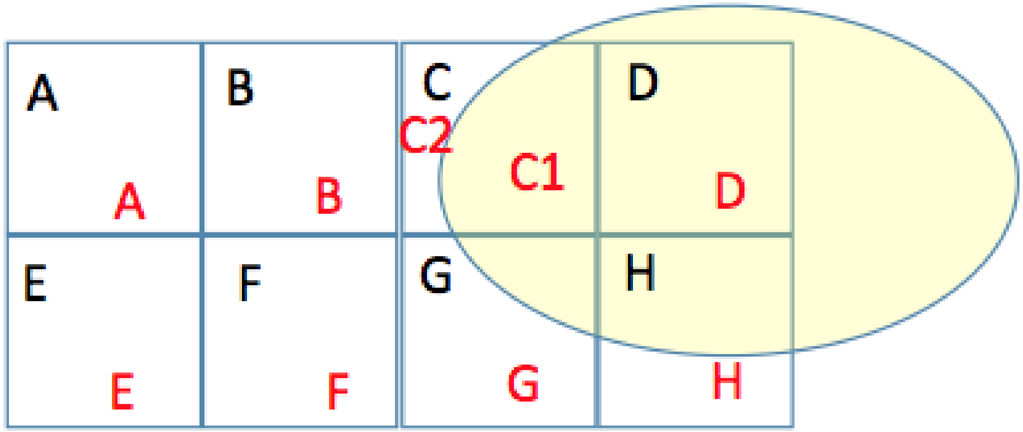


Figure 4: How the raster cells interpret the species data

3.11.4.11 Model description Global 2012: For the Species sub-goal, we used recent assessments by the International Union for Conservation of Nature (IUCN)- Global Marine Species Assessment of the extinction risk status of 2377 species for which distribution maps also exist across a wide range of taxa to provide a geographic snapshot of how total marine biodiversity is faring, even though it is a very small sub-sample of overall species diversity. The status of assessed species was calculated as the area- and threat status-weighted average of the number of threatened species within each 0.5 degree grid cell. Species distribution and threat category data came from the IUCN Global Marine Species Assessment results.

Global 2013: Same as Global 2012. However, see Evolution of the Approach for discussion of how data updates can affect goal scores.

Brazil: The status of assessed species was calculated as the threat status-weighted average of all species occurring in the Brazilian EEZ (we did not weight by area of occurrence as in Global 2012 because distribution maps were not available for all species at the time of this assessment). The sub-goal was therefore calculated at the national level, giving equal weight to all species occurring in Brazilian waters. Threat weights were assigned based on the IUCN threat categories status of each species.

US West Coast: Same as Global 2012.

3.11.4.12 Evolution of the approach Global 2012: We did not include ecological integrity measures as they are based on the same data used to calculate Status and Trend.

Global 2013: Updates were available for data used for this goal. It is important to note that extinction risk estimates for significantly more species were released in the past year, such that the scores needed to be updated for this sub-goal (and therefore the biodiversity goal overall) for 2012 to reflect improved reporting of species assessments (e.g., data quality). Actual changes in risk status from last year to this year occurred for only 15 of 6080 species, primarily because species are rarely re-assessed; in other words, only when species are reassessed can the status score of this sub-goal change.

Brazil: A list of marine species that occur in Brazil and were evaluated globally under the IUCN Red List assessment process was combined with a list of species assessed regionally in Brazil using the same criteria (Brazilian Red List assessments from Chico Mendes Institute for Biodiversity Conservation; see Data Layers). We substitute global assessments for regional (Brazil-specific) assessments whenever these were available. We had assessments for a total of 504 species.

US West Coast: Data were available at a regional scale, but the approach was the same as Global 2012.

3.11.4.13 The reference point **Global 2012:** The target for the species sub-goal is to have all species at a risk status of Least Concern. We scaled the lower end of the biodiversity goal to be 0 when 75% species are extinct, a level comparable to the five documented mass extinctions and that would constitute a catastrophic loss of biodiversity.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Same as Global 2012, with regional data for the threat categories.

3.11.4.14 Interpreting a score A score of 100 would indicate that over 75% of species have a 'least concern' risk of extinction.

3.11.5 HABITATS

3.11.5.1 Practical Considerations

3.11.5.2 ***Ideal Approach*** Ideally, information on the extent and condition of every single habitat type would be available. The reference point for habitat-based goals will likely be temporal; this means that historic data are needed such that current habitat and value data can be compared to historic data (or a proportion of historic data).

3.11.5.3 *History of the Approach (lessons learned 2014)*

3.11.5.4 Model description **Global 2012:** The status of the Habitat sub-goal was assessed for all habitats for which at least some global data were available, specifically: mangroves, coral reefs, seagrass beds, salt marshes, sea ice edge, and subtidal soft-bottom habitats. Status was assessed as the average of the condition estimates for each habitat present in a region.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012 for mangroves, coral reefs, seagrass beds, salt marshes, and subtidal soft-bottom habitats.

US West Coast: Same as Global 2012 for salt marshes, seagrasses, sand dunes, and soft-bottom habitats. Additionally, when assessing habitat condition, we used reconstructions of historic extents to set more ambitious targets.

3.11.5.5 Evolution of the approach **Global 2012:** A significant amount of pre-processing of the habitat data was needed to fill data gaps and resolve data quality issues (see the data layers section for details on data sources). Because consistent habitat monitoring data were unavailable for many regions, anomalous values can occur.

Global 2013: Same as Global 2012.

Brazil: Same as Global 2012.

US West Coast: Reliable, comprehensive habitat extent data prior to the 1990s are unavailable for most coastal regions within the U.S. Estimates of habitat loss since European settlement have been extrapolated in some regions for some habitats. However, while the habitat extent from the 1990s would represent a very un-ambitious target, a pre-industrialized reference point for habitat extent is considered an unrealistic goal under current conditions. To establish our temporal reference points we instead set our reference uniquely for each habitat, as a percentage of pre-industrialized habitat coverage for salt marshes; and as habitat extent between the 1950s and 1960s for sand dunes. We utilized pressures on habitats as a proxy of habitat condition for seagrasses and soft bottom habitats. The reference point:

Global 2012: In the global study, the current condition of salt marshes, seagrasses, mangroves and corals was compared to a reference year that is intended to represent optimal conditions (1980 for salt marshes and sand dunes, varied by site for seagrasses). We generally considered the reference years to be between 1980-1995 and the current years to be between 2001-2010, although these varied by habitat due to data availability.

Global 2013: Same as Global 2012.

Brazil: The timeframes between current and reference condition vary across habitats, but we generally used a 20-year gap. However, it is important to bear in mind that we were able to obtain only a few time-series in which habitat health was resampled through time, so that information from a few point estimates had to be used to infer the health of a large and highly heterogeneous region.

US West Coast: To establish our temporal reference points we instead set our reference uniquely for each habitat, as a percentage of pre-industrialized habitat coverage for salt marshes, as habitat extent between the 1950s and 1960s for sand dunes, or we utilized pressures on habitats as a proxy of habitat condition for seagrasses and soft bottom habitats.

3.11.5.6 Interpreting a score A score of 100 would indicate that habitat coverage had not reduced when compared to the temporal reference point.