The Ocean Health Index Conceptual Guide

Contents

1 Need for and Benefits of an Ocean Heath Index

> 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 to measure how sustainably people are using the ocean

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.

Overall Index scores are a combination of components, known as '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. Because the Index compares scores against the available data within the scope of the study area, it presents a highly tailorable framework to match an assessment approach. It is a structured approach, but the structure may change appropriately with each new assessment–and in fact, tailoring the approach is encouraged in order to best fit local needs using the best available data and indicators.

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. 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 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 such as the Millennium Development Goals because those systems typically contain a list of indicators each of which individually assesses performance in a particular task, sector, 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. 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 as well.

2 Task Timeline

> TIP: The process of conducing an OHI+ assessment is not necessarily linear.

The Task Timeline provides the steps involved in conducting Ocean Health Index assessments. It also recommends the the types of skills needed. The process of calculating the Index is not linear. There is a lot of iteration and discussion among the team, which consists of scientists, computer programmers, and a core management team, who must all work together to arrive at the best decisions possible. For example, gathering appropriate data for each status, pressure, and resilience layer requires serious thinking about how to calculate reference points at the same time as determining the validity and usability of the dataset. It is expected that your data sources and goal models will change during the process.

The Task Timeline outlines four phases for the OHI+ process. It shows the proposed roles required for a team. Although there is a suggested timeline, the amount of time actually required required to do an assessment will vary depend on a number of factors–time is often limited, for example, by the availability of data and the number of people working on the assessment. The process may be slowed by unforeseen challenges such as technical issues with software.

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 OH+ Assessment
- **Phase 4:** Communicate

> For more information, visit: http://ohi-science.org.

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.

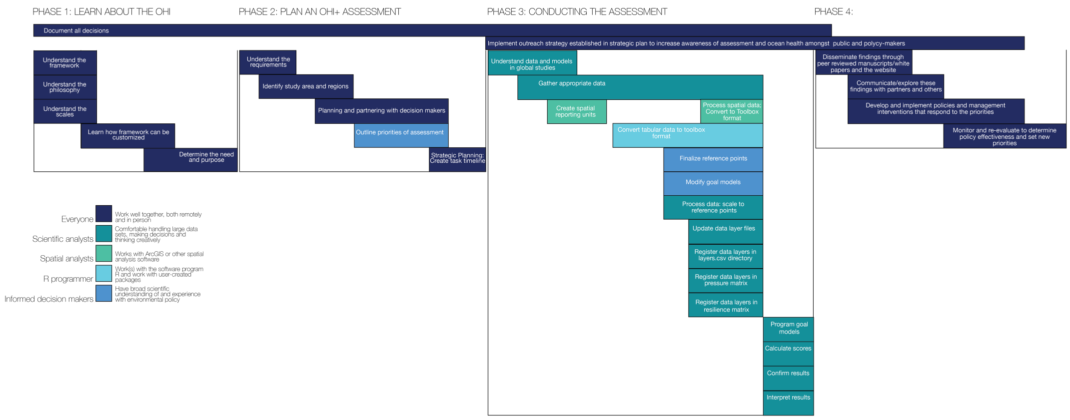


Figure 1: A timeline of the OHI+ assessment process.

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.

In this section you will learn how to:

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

- Understand the OHI philosophy
- Methods
- Resources

- Design adaptive management strategies

- 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

3.1 What is the Ocean Health Index?

The Ocean Health Index scores important **Goals** of ocean health. The Ocean Health Index defines a healthy ocean as one that can sustainably deliver a range of benefits to people now and in the future, while not compromising the state of the oceans and coasts. A healthy ocean in this definition, however, is not necessarily a pristine ocean, although the Index allows for pristine systems as well as sustainably used systems to score highly. In fewer words, the OHI is about balance.

The OHI framework is distinct from assessment-specific input information. The framework itself is structured around defined ocean-derived goals coupled with findings of the likely future state, pressures and resilience, while the data and indicators used in the assessment, and the goal models developed, are set based on data in the local context. The scores are calculated using the best available data and indicators at the scale of the assessment.

A score of 100 means that the evaluated system achieved its defined target (reference point) for that goal, is sustainably delivering all of the specified benefits and is likely to continue doing so in the near future. A score of 0 means that global data were available, but that the country either did not achieve any of the available benefits or that the benefits it did obtain were gained in an unsustainable manner.

Scores reflect how well coastal regions optimize their potential ocean benefits and services in a sustainable way relative to a reference point, also known as a target, on a scale of 0 to 100. Because the Index compares scores against the available data within the scope of a given study area, it presents a highly tailorable framework and can match an assessment's geographic scope. It is a structured approach, but the structure may change appropriately with each new interpretation.

> A flexible framework such as the OHI allows assessments to adapt to local context while still being broadly comparable across regions.

Outside partners are using the OHI in their own assessments. These are modifications and interpretations of the original Global Assessments conducted for the first time in 2012 (Halpern *et al.* 2012). The methods have improved since then, and collaborators have changed their goals, models, and data in their own assessments in the ever-evolving OHI process. This **Conceptual Guide** will help you understand the reasoning behind the framework, and will allow you to prepare to make use of local information to get the best results possible for your assessment once you are ready to engage with the data.

The benefits provided by the ocean have most commonly been measured through these 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 **Food Provision** is to optimize the sustainable level of seafood harvest in your region's waters.

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

3.2.1 Wild-Caught Fisheries

> The **Wild-Caught Fisheries** sub-goal describes the amount of wild-caught seafood harvested and its sustainability for human consumption.

Higher scores reflect fishing practices with sustainably high yields that avoid excessively high exploitation and do not target threatened existing fish populations.

3.2.1.1 Philosophy This sub-goal 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. The optimal levels are described by Maximum Sustainable Yield (MSY). Higher scores reflect fishing practices with sustainably high yields that avoid excessively high exploitation (i.e., overfishing), and do not target threatened populations.

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.

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.

3.2.1.2 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 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.

3.2.1.3 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	Status of the Fisheries sub-goal was calculated as a function of the absolute difference betwee
Global 2013	Status of the Fisheries sub-goal was calculated based on estimating population biomass relativ
Brazil (2014)	Status of the Fisheries sub-goal was calculated in the same manner as Global 2012, with a mo
U.S. West Coast (2014)	Status of the Fisheries sub-goal was based on population biomass relative to the biomass that

3.2.1.4 History of the Approach

3.2.2 Mariculture

> **Mariculture** measures the ability to reach the highest levels of seafood gained from far-raised facilities without damaging the ocean's ability to provide fish sustainably now and in the future.

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.

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.total yield it contributes to total food provision.

3.2.2.1 Philosophy 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.

3.2.2.2 Ideal Approach 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 fin-fish 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.

3.2.2.3 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	Mariculture was calculated as the yield reported to the United Nations Food and Agriculture
Global 2013	A similar model to the one developed previously in Global 2012 was used in Global 2013; how
Brazil (2014)	The status of the Mariculture sub-goal was calculated using harvest data reported by the Bra
U.S. West Coast (2014)	The status of the Mariculture sub-goal was calculated as the sustainable production density o

3.2.2.4 History of the Approach

3.2.3 Practical Considerations

3.2.3.1 Ideal Approach 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.

3.2.3.2 Recommendations for your assessment: 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 your assessment 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.

3.2.5 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.

3.2.5.3 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.

3.3 Artisanal Fishing Opportunities

> The **Artisanal Fishing Opportunties** goal shows whether people with the desire to fish on small scales have the opportunity to do so.

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.

3.3.0.4 Philosophy 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).

3.3.0.5 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 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.

3.3.0.6 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	Status for this goal is measured as the demand for opportunities to fish artisanally. Demand i
Global 2013	Same as Global 2012. No data update available.
Brazil (2014)	Economic or physical access or demand to fishing were not deemed to reflect circumstances in
U.S. West Coast (2014)	We developed a model using physical and economic access to coastal areas and access to the b

3.3.0.7 History of the Approach

3.3.0.8 Practical Considerations

3.3.0.9 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 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.

3.3.0.10 Recommendations for your assessment 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.

3.4 Natural Products

> The **Natural Products** goal describes how sustainably people harvest non-food products from the sea.

4 Philosophy

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.

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.

4.0.0.11 Ideal Approach 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.

4.0.0.12 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	For the status of each product, we assessed the most recent harvest (in metric tons) per regior
Global 2013	This used the same approach as Global 2012. Data processing did change however; see below
Brazil (2014)	This used the same approach as Global 2012.Same approach as Global 2012.
U.S. West Coast (2014)	The Natural Products score was not calculated because there are few data available on local-s

4.0.0.13 History of the Approach

4.0.0.14 Practical Considerations

4.0.0.15 ***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.

4.0.0.16 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.

4.0.0.17 Global Data Approach **Data Overview**

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	–

(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

4.0.0.18 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.

4.0.0.19 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

4.0.0.20 Preparing the Data

Notes from Katie while updating the NP goal:

Natural products **harvest:** - explore simplifying gap-filling: use correlation model of dollar value vs harvested tonnage, while discarding the part of script using dollar ratio (curr dollar value/peak dollar value) as a gap-filler for harvest ratio - switch the gap-filling order: using the dollar value correlation model first (in cases where the most recent year has no harvest reported but has dollar value reported, that's a better estimate than using the harvest from the previous year), then gap-fill any remaining cases of missing harvest for the current year with harvest from the previous year

sustainability: - check cases where country-product pair has 0 for sustainability score, but relatively high harvest ratio (curr harvest/peak harvest) – it may be a flag that the sustainability score is off (eg because the habitat area is off)

4.0.0.21 Tech Specs Updating the Script

I just pushed a new script, `data_prep_2015a.R`, and the resulting outputs to `ohiprep/globalprep/fao_commodities/v2015`. The new script reworks the gap-filling, based on Mel's and Katie's suggestions. I'll post later about the smoothing and calculations based on new input from Katie, but would love to get input on the gap-filling first. * Before gap-filling, binds the USD and tonnes data for all natural products at the commodity level (rather than product level). * By commodity & year: Identifies years with neither USD nor tonnes data, flags as `no_data`, and determines first reporting year based on first year with either data (and deletes years prior to this). * By commodity & year: Gap-fills according to these rules: * If `no_data`, and not the last year of data set, assume that non-reporting means zero harvest; replace `NA` with `0` for both USD and tonnes * Create regression models for `(tonnes ~ USD)` and `(USD ~ tonnes)` * Exclude NAs (these will be in either USD or tonnes, but not both) * Remove all commodities with fewer than four non-zero observations (within a particular region) * not enough info for a decent regression or meaningful peak * counting these could also penalize experimental production that later stops * Use `lm()` to generate slope/intercept, and gap-fill all NAs with the appropriate regression model * Regression gap-filling takes care of the most current-year gaps, per Katie's comment * Regression gap-filling fails for certain data, where there are no paired observations for correlation (e.g. every reported value for USD shows NA for tonnes, and/or vice versa), still need to figure out how to deal with those without losing useful data. * If `no_data` appears in most recent year of data set, not applicable for regression gap-fill, so end-fill based upon the prior year. * Outputs a .csv with rgn_id, commodity, product, year, and gapfill method at the commodity level. I made up text codes for now, pretty self-explanatory, but those are easy to change. File is `data/np_gapfill_report.csv` if you want to take a peek. * Collapses commodities into products at this point, in preparation for smoothing, finding peaks, and determining status and weighting.

Latest on NP: in ohiprep/globalprep/FAO-commodities, new (well, a week or so ago) data_prep2015.R that fixes: * the FAO data cleaning, so treats '0 0' as 0.1 instead of NA * gap filling: * it runs at commodity level instead of product level * gapfills between USD and tonnes in sequence: local regression, then georegional regression, then global regression. * does all that before end-filling. * produces a gapfilling report for every commodity/region/year. Currently this outputs a single file; needs to be updated to output individual files for tonnes, tonnes_rel, and prod_weight. Needs to be renamed to data_prep.R.

In ohi-global/eez2013, LSP_update branch, I've updated /conf/functions.R - cleaned up (dplyr, etc), chunked into sub-functions. Questions that need to be addressed: * currently calcs trend using last five years of data (year_max >= year > year_max-5), which means only four intervals for the regression. I think we want to include the (year_max - 5) data, for five intervals, so: (year_max >= year >= year_max-5). * currently, for regions with exposure = NA, replaces NAs with zero. Should these be replaced with one instead? * Exposure for these indicates harvest intensity (tonnes/km^2) relative to the region with the max harvest intensity.
* NAs occur when a country hasn't reported area values for rocky (seaweeds), coral (corals), so tonnes/NA = NA. * Setting exposure to zero means intensity = none at all (boosting the status); leaving as NA removes from calculation (ignored in status); setting to one means intensity = worst case (penalizing the status).

Almost there!

4.1 Carbon Storage

> **Carbon Storage** describes how much carbon is stored in natural coastal ecosystems. These ecosystems 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.

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 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 carbon dioxide, the primary heat-trapping gas in the Earth's atmosphere, is released.

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.

4.1.0.22 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 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.

4.1.0.23 Keep in Mind

Because they store carbon for less than 100 years, seaweeds and corals were not included in the carbon storage goal in the Global assessments. 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.

Assessment	Model Description and Reference Point
Global 2012	The status of Carbon Storage is measured as a function of its current 'condition' relative to a
Global 2013	Same as in Global 2012. Improvements in data processing are outlined below in Evolution of t
Brazil (2014)	The goal model was the same as in Global 2012.The reference condition was determined speci
U.S. West Coast (2014)	We used reconstructions of historic extents compared to current habitat coverage to set more

4.1.0.24 History of the Approach

4.1.0.25 Practical Considerations

4.1.0.26 Ideal Approach

Ideally, information would be available to allow you to to assess the amount of carbon stored in every coastal habitat. The best information would show area covered and some measure of the quality of the habitat for this goal. For example, a dense mangrove forest would be better quality than a sparse mangrove forest. Additionally, different weights would be assigned to the habitats based on their relative ability to store carbon, and this factor could be used to penalize areas where there is greater loss of carbon and reward areas where this is a greater storage of carbon. The carbon storage model could then incorporate such weights in a similar way to the **Coastal Protection** goal. The reference point for habitat-based goals will likely be temporal in most cases. This means that historic data are needed so that current habitat values can be compared to a past state.

> TIP: Understanding habitat storage is an active area of ongoing research. The capacity for habitats to store carbon varies with ecological factors including the morphology of plants in the system.

4.1.0.27 Recommendations for your assessment

The overall **Carbon Storage** model and approach should not change from what is used in the current Global model. Knowing the area and the condition of of carbon-storing habitats are the two components that are most important. For example, if you have area of mangrove coverage and density of the mangroves within that area, you will find more robust results. It may not be the case in practice to have both variables, however.

4.1.0.28 Where to Look? 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.

4.2 Coastal Protection

> **Coastal Protection** describes 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.

4.2.0.29 Philosophy 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.

4.2.0.30 Ideal Approach 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.

4.2.0.31 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	The status of this goal was calculated to be a function of the amount and/or condition (deper
Global 2013	The model was the same as in Global 2012.The reference point was the same as Global 2012.
Brazil (2014)	Same goal model as Global 2012, using local data.To calculate the reference state for coral ree
U.S. West Coast (2014)	Same as Global 2012, with more ambitious reference points for target habitat coverage.Reliab

4.2.0.32 History of the Approach

4.2.0.33 Practical Considerations

4.2.0.34 ***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.

4.2.0.35 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.

4.3 Coastal Livelihoods and Economies

> The **Coastal Livelihoods and Economies** goal rewards productive coastal economies that avoid the loss of ocean-dependent livelihoods while maximizing livelihood quality.

This goal is founded on two sub-goals, **Livelihoods** and **Economies**. **Livelihoods** is comprised of jobs and wages, and **Economies** is comprised of 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).

4.3.0.36 Keep in Mind Maintaining jobs in this case means not losing jobs–this sub-goal does not give credit for *gaining* jobs in the Global model. It does not attempt to capture aspects of job identity like reputation, desirability, or other social or cultural perspectives associated with different jobs, nor does it account for the impact upon an individual but rather focuses on the aggregate. One can examine the component parts that make up this goal, however, to evaluate individual sectors and infer implications for job identity.

4.3.1 Livelihoods

> The **Livelihoods** sub-goal describes livelihood quantity and quality.

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.

4.3.1.1 Philosophy 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.

4.3.1.2 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 or a spatial comparison.

Assessment	Model Description and Reference Point
Global 2012	This sub-goal is measured as the number of direct and indirect jobs across sectors within a re
Global 2013	Based on Global 2012, with some simplifications: Since many of the values were not available
Brazil (2014)	The model and reference point were the same as Global 2012.
U.S. West Coast (2014)	This goal follows the same model as in Global 2012, but using local data with a slightly differ

4.3.1.3 History of the Approach

4.3.2 Economies

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

4.3.2.1 Philosophy 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. The economies sub-goal is composed of a single component, revenue.

4.3.2.2 Ideal Approach Ideally, economic data would be collected for each coast, 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.

4.3.2.3 Keep in Mind The definition of a marine-related sector can vary. There are jobs that are directly connected to the marine environment, such as shipping, fishing, longshore workers, but also some that are connected indirectly, such as supplies and supporting industries. The use of multipliers in attempts to capture the indirect revenue generated by jobs more indirectly associated to marine sectors is a well-established method in economics, and is encouraged in this approach.

Assessment	Model Description and Reference Point
Global 2012	This sub-goal is captured as the total adjusted revenue generated directly and indirectly from e
Global 2013	The model was same as Global 2012, with a few simplifications: revenue data were adjusted by
Brazil (2014)	The model and reference point were the same as Global 2012.
U.S. West Coast (2014)**	The model and reference point were the same as Global 2012.

4.3.2.4 History of the Approach

4.3.3 Practical Considerations

4.3.3.1 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.

4.3.4 LIVELIHOODS

4.3.4.1 Practical Considerations

4.3.4.2 *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.

4.3.4.3 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, such as shipping, fishing, longshore workers, but also some that are connected indirectly, such as supplies and supporting industries. The use of multipliers in attempts to capture the indirect revenue generated by jobs more indirectly associated to marine sectors is a well-established method in economics, and is encouraged in this approach. 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).

4.3.4.4 Global Data Approach In the past, the International Labour Organization provided wage data for ~150 occupations. We then categorized these occupations to get wage data for 5 major occupations related to marine environments:

Tourism Commercial Fishing Transportation & Fishing Ports & Harbors Ships & Boat Building Here is a table summarizing how these data were grouped:

4.3.5 ECONOMIES

4.3.5.1 Practical Considerations

4.3.5.2 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.

4.3.5.3 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.

4.4 Tourism and Recreation

> The **Tourism and Recreation** goal captures the value people have for experiencing and taking pleasure in coastal areas.

4.4.0.4 Philosophy 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.

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.

4.4.0.5 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.

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.

4.4.0.6 Keep in Mind **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.

Assessment	Model Description and Reference Point
Global 2012	Data on international arrivals were used as a proxy for the value of tourism and recreation in
Global 2013	We calculated the proportion of direct employment in the tourism industry relative to total la
Brazil (2014)	The model developed for Global 2012 was changed to use information on hotel employees for
U.S. West Coast (2014)	At this scale we were able to make use of detailed studies documenting the changes in partici

4.4.0.7 History of the Approach

4.4.0.8 Practical Considerations

4.4.0.9 ***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.

4.4.0.10 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.

4.5 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.

4.5.1 Iconic Species

> The **Iconic Species** sub-goal assesses the threat to species that are important to a region.

4.5.1.1 Philosophy Iconic species are defined as those that are relevant to local cultural identity through one of several ways. They can be identified through traditional activities such as fishing, hunting or commerce; through local ethnic or religious practices; through existence value; and through locally-recognized aesthetic value. This can even include, for example, touristic attractions/common subjects for art such as whales).

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.

4.5.1.2 Ideal Approach 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.

4.5.1.3 Keep in Mind This is in contrast simply an economic or extractive reason for valuing the species.

Assessment	Model Description and Reference Point
Global 2012	Status of this sub-goal is the average extinction risk of iconic species, calculated as the weight
Global 2013	The methods and reference point were the same as Global 2012.
Brazil (2014)	The methods and reference point were the same as Global 2012.
U.S. West Coast (2014)	To assess the status of these iconic species within the region we used the same methods outlin

4.5.1.4 History of the Approach

4.5.2 Lasting Special Places

> The **Lasting Special Places** sub-goal captures the conservation status of geographic locations that hold significant aesthetic, spiritual, cultural, recreational, or existence value for people.

4.5.2.1 Philosophy 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.

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.

4.5.2.2 Ideal Approach 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.

Assessment	Model Description and Reference Point
Global 2012	The status of this sub-goal is calculated by combining the percent of coastal waters that are c
Global 2013	The model and reference point were the same as Global 2012.
Brazil (2014)	The model and reference point were the same as Global 2012.
U.S. West Coast (2014)	The model and reference point were the same as Global 2012.

4.5.2.3 History of the Approach

4.5.3 Practical Considerations

4.5.3.1 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.

4.5.4 ICONIC SPECIES

4.5.4.1 Practical Considerations

4.5.4.2 ***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.

4.5.4.3 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).

4.5.4.4 Global Data Approach For the global assessment, we started with a list of iconic species, and then found which ones had been assessed, in this case by IUCN. So from that original list of iconic species, we could only include the ones assessed by IUCN. IUCN scores are categorical ('extinct', 'least concern', etc), but Butchart et al. (attached) had done a study where they assigned numeric scores to each IUCN category. So we took the list of iconic species that had IUCN categories and assigned Butchart's numeric scores to each species based on these categories. We found how many species were in each IUCN category, (% or proportion of species in 'least concern' compared to all species with IUCN categories). For each region in the global assessment, we averaged the scores of the species that were there in that region together, giving that region's ICO score. (This averaging assumes that all species are of equal importance). So for an example, let's say there are 10 assessed iconic species: 5 are 'least concern', 4 'vulnerable', and 1 'threatened'. The math would be (5lc + 4v + 1t) / 10. Or, to think about this as percentages, it could be 0.5lc + 0.4v + 0.1t. Are you using IUCN categories? If so, you can use Butchart's method. You'll see in the Toolbox that they assign the scores such that we actually have to do (1-Butchart_score) but the logic of what we did is the same.

For Global 2015, we are going to calculate SPP using both methods and evaluate (or present both).

4.5.4.5 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."

4.5.5 LASTING SPECIAL PLACES

4.5.5.1 Practical Considerations The type of reference point used will depend on the data available.

4.5.5.2 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.

4.6 Clean Waters

> The **Clean Waters** goal captures the degree to which local waters are polluted by natural and human-made causes.

4.6.0.3 Philosophy 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.

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.

4.6.0.4 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.

4.6.0.5 Keep in Mind 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.

Assessment	Model Description and Reference Point
Global 2012	We aggregated various measures of pollution into four components that comprise the Clean W
Global 2013	The goal model and reference point were the same as Global 2012.
Brazil (2014)	The goal model and reference point were the same as Global 2012.
U.S. West Coast (2014)	The model was the same as Global 2012, with regional instead of global data.The reference po

4.6.0.6 History of the Approach

4.6.0.7 Practical Considerations

4.6.0.8 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.

4.6.0.9 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.

4.6.0.10 Global Data Approach One approach: instead of using population trend as proxy for trash trend, use trash trend when you have it, otherwise population trend

Using the new data from 5 gyres on plastic pollution in the worlds oceans, I've created initial pressure layers using our 'decision tree'. I'll walk through them here and would like any feedback.

The data came to us in two formats - count of plastics (g) per km2 and weight of plastics per km2. Each of these types of data has 4 different size classes. You can see all eight of these data types from the figures below (from the paper). Native resolution is ~0.2 x 0.2 degrees.

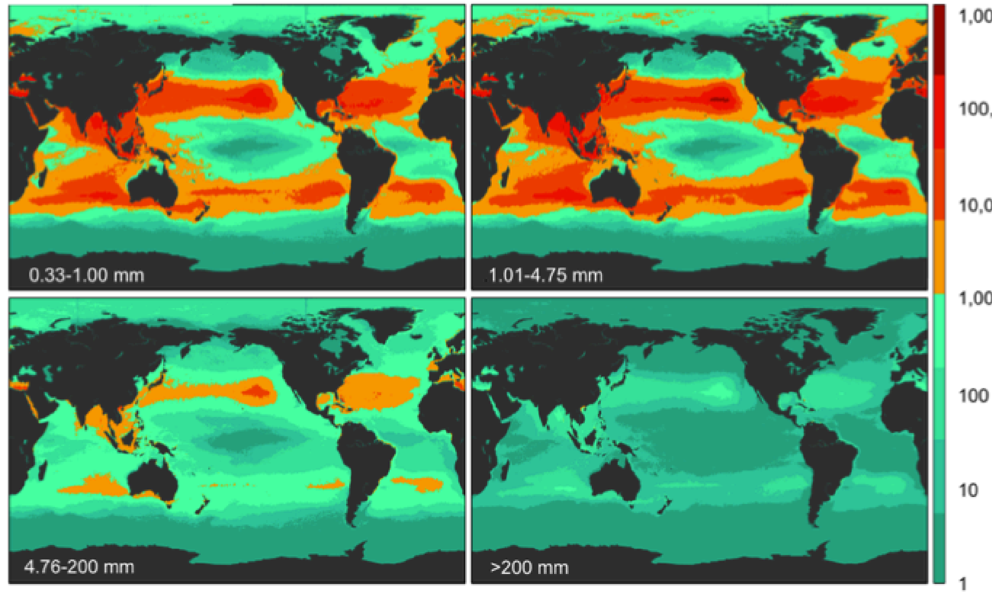


Figure 2. Model results for global count density in four size classes. Model prediction of global count density (pieces
four size classes (0.33–1.00 mm, 1.01–4.75 mm, 4.76–200 mm, and >200 mm).

Count density across 4 size classes

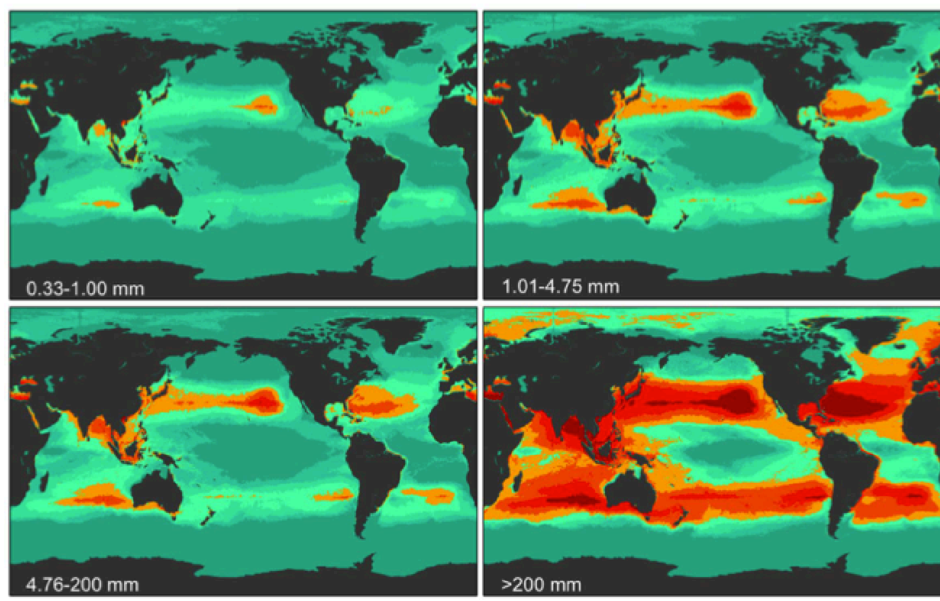


Figure 3. Model results for global weight density in four size classes. Model prediction of global weight density (
size classes (0.33–1.00 mm, 1.01–4.75 mm, 4.76–200 mm, and >200 mm). The majority of global weight is from th

Weight density across all 4 size classes

To turn these data into layers for OHI, I **summed across all four size classes for both weight and count**, then ran them through the 'decision tree' (#389).

4.7 Biodiversity

The **Biodiversity** 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.

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.

4.7.1 Species

> The **Species** sub-goal aims to estimate how successfully the richness and variety of marine life is being maintained.

4.7.1.1 Philosophy 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.

4.7.1.2 Keep in Mind It 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.

4.7.1.3 Ideal Approach 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.

Assessment	Model Description and Reference Point
Global 2012	For the Species sub-goal, we used recent assessments by the International Union for Conservat
Global 2013	The goal model and reference point were the same as Global 2012.
Brazil (2014)	The status of assessed species was calculated as the threat status-weighted average of all speci
U.S. West Coast (2014)	The model description and reference point were the same as Global 2012, with regional data a

4.7.1.4 History of the Approach

4.7.2 Habitats

> The **Habitats** sub-goal measures the condition of habitats that are important for supporting a wide array of species diversity.

4.7.2.1 Philosophy 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.

4.7.2.2 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.

4.7.2.3 Keep in Mind

Assessment	Model Description and Reference Point
Global 2012	The status of the Habitat sub-goal was assessed for all habitats for which at least some global
Global 2013	The goal model and reference point were the same as Global 2012.
Brazil (2014)	The goal model was the same as as Global 2012 for mangroves, coral reefs, seagrass beds, salt
U.S. West Coast (2014)	Same as Global 2012 for salt marshes, seagrasses, sand dunes, and soft-bottom habitats. Addi

4.7.2.4 History of the Approach

4.7.3 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.

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.

4.7.3.0.1 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.

4.7.4 SPECIES

4.7.4.1 Practical Considerations

4.7.4.2 *Ideal Approach*

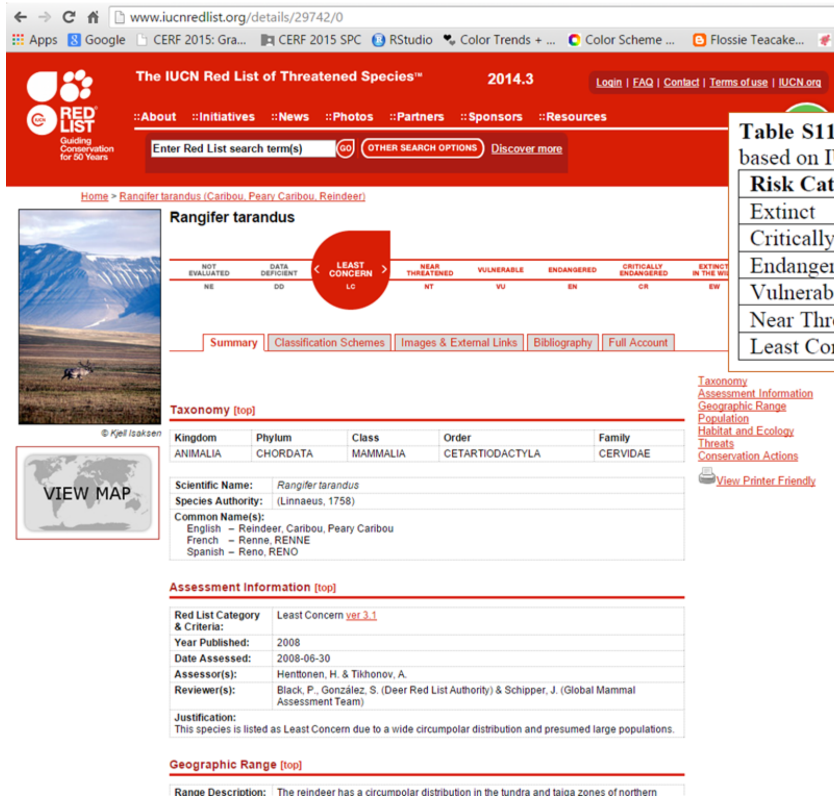
Ideally, data would be available on the number of species, their habitat range, and assessments of their population or conservation status. The type of reference point used will depend on the data available.

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.

4.7.4.3 Preparing Data

4.7.4.3.1 SPP: Based on two primary types of data

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

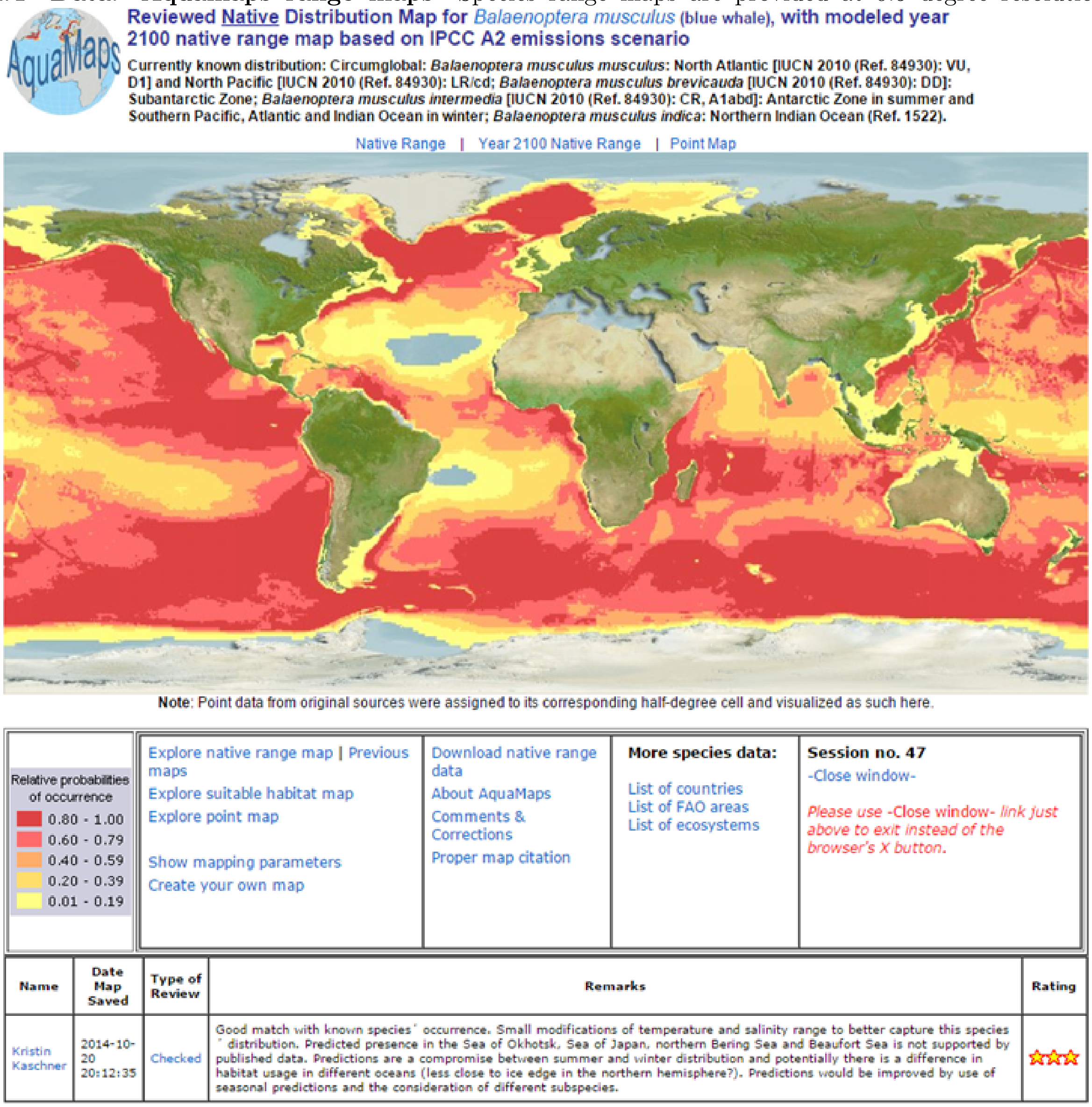


4.7.4.3.2 Data: IUCN extinction risk status

(there are also range maps available from their website)

4.7.4.4 Data: Aquamaps range maps

Species range maps are provided at 0.5 degree resolution:



4.7.4.5 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

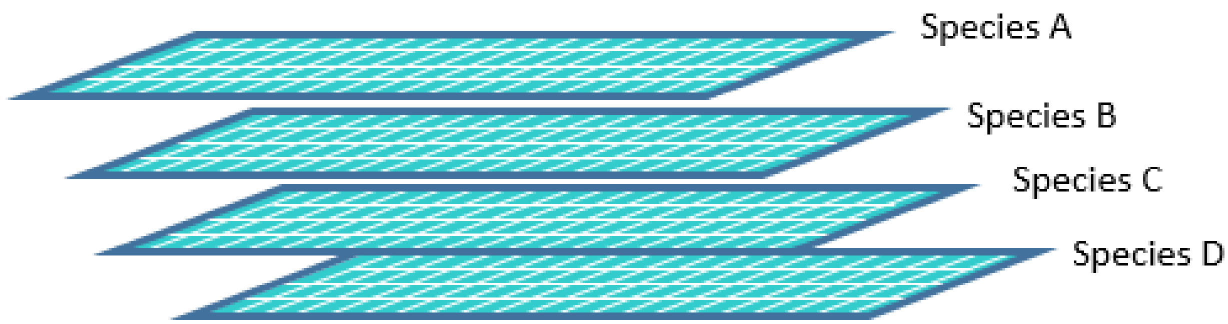


Figure 2: image

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).

4.7.4.6 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.

4.7.4.7 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).

4.7.4.8 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."

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

4.7.5 HABITATS

4.7.5.1 Practical Considerations

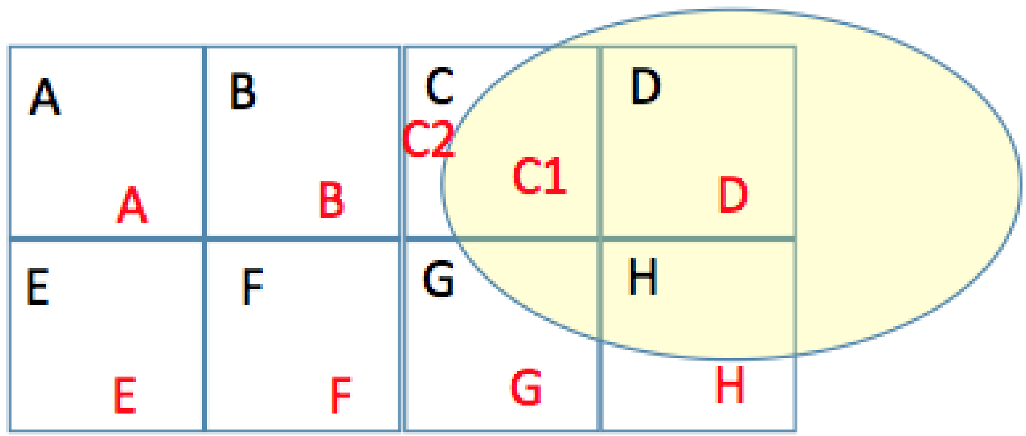


Figure 4: How the raster cells interpret the species data

4.7.5.2 ***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).

4.7.5.3 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.

4.7.5.4 Global Data Approach Hi Julie: I'm not sure if this is an adequate answer, but we can start discussing this!

4.7.5.5 habitat extent: Area of each habitat in each reporting region

4.7.5.6 habitat health/condition: this is the condition of the habitat relative to a reference point. The ideal situation is if there is historical data that can be compared to the present habitat. Some examples: For mangroves, we divided the current area (2005 data) by the reference area (1980 data).

Coral health is based on the % living cover on a reef. Ideally, historical data is available that can provide a reference point for % living cover. For our reference point, we used the mean predicted values for a country from 1985-1987. When this data was not available for a country, we used the value of neighboring countries. (There was also some analyses to control for the fact that the % live coral cover naturally varies over time, hence the use of "predicted values").

For soft-bottom habitat, we estimated status based on the intensity of trawl fishing as a proxy (pages 51 and 52 of SOM 2012).

4.7.5.7 habitat trend: Change in health/condition over time Ideally, there will be enough years of data to directly calculate the recent change in health of the habitat (i.e., using a linear model to calculate trend). For example, for sea ice, we fit a linear model to a metric of sea ice cover for data from 2006-2011 (after some smoothing to account for natural variation).

This isn't always the case, and proxies or estimates might need to be used. For example, due to spotty salt marsh data we created trend categories of increasing (0.5), stable (0), and decreasing (-0.5) based on available data.

4.7.5.8 Questions to Consider I think the approach is going to largely depend on the type of data they have (our approach varies for each habitat because the data is so variable).

Do they have maps, for example, that show current habitat distributions and maps that show historical habitat distributions? If so, they could extract that data for each of their regions to get a current and reference area. Or, they may have access to summarized habitat data that exists in tables for their regions (or, at smaller scales such as estuary that they can summarize per region)?

Antarctica had sea ice habitat data, there is a script that wallks through downloading and analyzing the data. But, I'm not sure how helpful that will be.

For Fiji, the only habitat variable that we modified was coral health. In this case, we had better regional data to estimate coral health (even though the final value we ended up getting was the same). That was a fairly specialized analysis