1 The Theory
2 Data inclusion and data gaps
3 Regions
4 Models
5 Goal models and data
6 Description of data layers
References

Code

Ocean Health Index 2018: Methods

Compiled on Wed Nov 28 11:01:53 2018.

1 The Theory

1.1 A comprehensive framework to assess ocean health

The Ocean Health Index assesses ocean health which we define as how well we are sustainably managing the resources that we want and need from the ocean (e.g., tourism and recreation, food provisioning).

The OHI is considered a *composite indicator* because it combines many indicators into a comprehensive framework describing ocean health. This is in contrast to focusing on individual indicators, such as phosphate levels, sedimentation, biodiversity, etc. Individual indicators are important, but they provide limited information when it comes to evaluating how well an overall ecosystem is functioning. Another shortcoming of individual indicators is that they do not directly describe what we actually care about, and consequently, focusing on them can hinder communication. For example, most people do not directly care about nutrient pollution, however, we do care about its effects on the ocean's ability to provide recreation and food.

Without an overall framework to evaluate indicators, certain indicators may be overemphasized relative to their true importance due to researcher bias (most researchers believe their area of study is the most important), trends in research (what is currently considered a hot topic and is funded), and availability of data (e.g., some data is easier to collect). A model that combines multiple indicators will inevitably have flaws, but at least we know which variables are included and how they are weighted.

1.2 The role of humans

One of the primary contributions of the OHI is that it recognizes people are an important part of the marine system. Both conservation and extractive use of ocean resources are valued, and consequently, scores are highest when we maximize the benefits we receive while maintaining sustainability so we can continue to receive benefits now and into the future. One temptation of indicator development is to focus only on the pressures that humans apply to systems. This makes sense because we want to be sure we are adequately protecting resources. However, eliminating all pressures on the ocean would require eliminating all contact between humans and the ocean. Beyond being unrealistic, this is undesirable because we would stop receiving all the benefits that we rely on from the ocean. The OHI is unique because it tracks both the pressures we put on oceans as well as the benefits we receive.

1.3 Yearly assessments

The global Ocean Health Index has been assessed every year since 2012. The primary goal of each yearly assessment is to calculate a new year of scores using the most recent data. Often, in addition to incorporating an additional year of data, we make improvements to models or decide to use different data sources. To ensure that scores for all years are comparable, we recalculate scores for previous scenario years for each assessment using new methods and data sources. For the current assessment, for example, in addition to calculating the current year's scores, we recalculate scores for every year since 2012. Consequently, comparisons among years should always be performed using data from the same assessment year so trends in scores reflect changes to ocean health rather than changes to methods.

Not all data layers are reported through the most current assessment year, and consequently, the OHI scores are calculated using the most recent year of available data. Details on which years are used for each data layer are provided in Table 6.2.

1.4 For more information

For more information about the philosophy of the Ocean Health Index and model development see Halpern et al. (2012, 2015) and http://ohi-science.org/ohi-global/ (http://ohi-science.org/ohi-global/), which includes information about downloading global ocean health data.

The Index is designed to be flexible so it can accommodate different scales and geographies of interest and different and new types of data (Lowndes et al. 2015, http://ohi-science.org (http://ohi-science.org)). Currently, many countries are conducting local OHI assessments.

1.5 Brief anatomy of OHI scores

We define ocean health as the sustainable delivery of ten widely-held public goals for ocean ecosystems (Table 1.1). These goals represent the full suite of benefits that people want and need from the ocean, including the traditional 'goods and services' people often consider (e.g., fish to eat, coastal protection from nearshore habitats) as well as benefits less commonly accounted for, such as cultural values and biodiversity. Within each region, scores, ranging from 0 to 100, are calculated for the 10 goals (section 4.2). Four of the goals are calculated from 2 subgoals. The subgoals are calculated independently (i.e., they are treated as if they are goals) and then combined into the goal status score (Table 1.2).

Table 1.1. The 10 goals of the Ocean Health Index

Goal	Abbreviation	Description
Artisanal Fishing Opportunity	AO	The opportunity for small-scale fishers to supply catch for their families, members of their local communities, or sell in local markets
Biodiversity	BD	The conservation status of native marine species and key habitats that serve as a proxy for the suite of species that depend upon them
Carbon Storage	CS	The condition of coastal habitats that store and sequester atmospheric carbon
Clean Waters	CW	The degree to which ocean regions are free of contaminants such as chemicals, eutrophication, harmful algal blooms, disease pathogens, and trash
Coastal Livelihoods and Economies	LE	Coastal and ocean-dependent livelihoods (job quantity and quality) and economies (revenues) produced by marine sectors
Coastal Protection	CP	The amount of protection provided by marine and coastal habitats serving as natural buffers against incoming waves
Food Provision	FP	The sustainable harvest of seafood from wild-caught fisheries and mariculture
Natural Products	NP	The natural resources that are sustainably extracted from living marine resources
Sense of Place	SP	The conservation status of iconic species (e.g., salmon, whales) and geographic locations that contribute to cultural identity
Tourism and Recreation	TR	The value people have for experiencing and enjoying coastal areas through activities such as sailing, recreational fishing, beach-going, and bird watching

Table 1.2. Subgoals used to calculate 4 of the Ocean Health Index goals

Subgoal	Goal	Abbreviation	Description
Habitat	Biodiversity	HAB	The status of key habitats that serve as a proxy for the suite of species that depend upon them
Species condition	Biodiversity	SPP	The conservation status of native marine species
Livelihoods	Coastal livelihoods and economies	LIV	Coastal and ocean-dependent livelihoods (job quantity and quality) produced by marine sectors
Economies	Coastal livelihoods and economies	ECO	Coastal and ocean-dependent economies (revenues) produced by marine sectors
Fisheries	Food provision	FIS	The sustainable harvest of seafood from wild-caught fisheries
Mariculture	Food provision	MAR	The sustainable harvest of seafood from mariculture practices
Iconic species	Sense of place	ICO	The conservation status of iconic species (e.g., salmon, whales) that contribute to cultural identity
Lasting special places	Sense of place	LSP	The conservation status of geographic locations that contribute to cultural identity

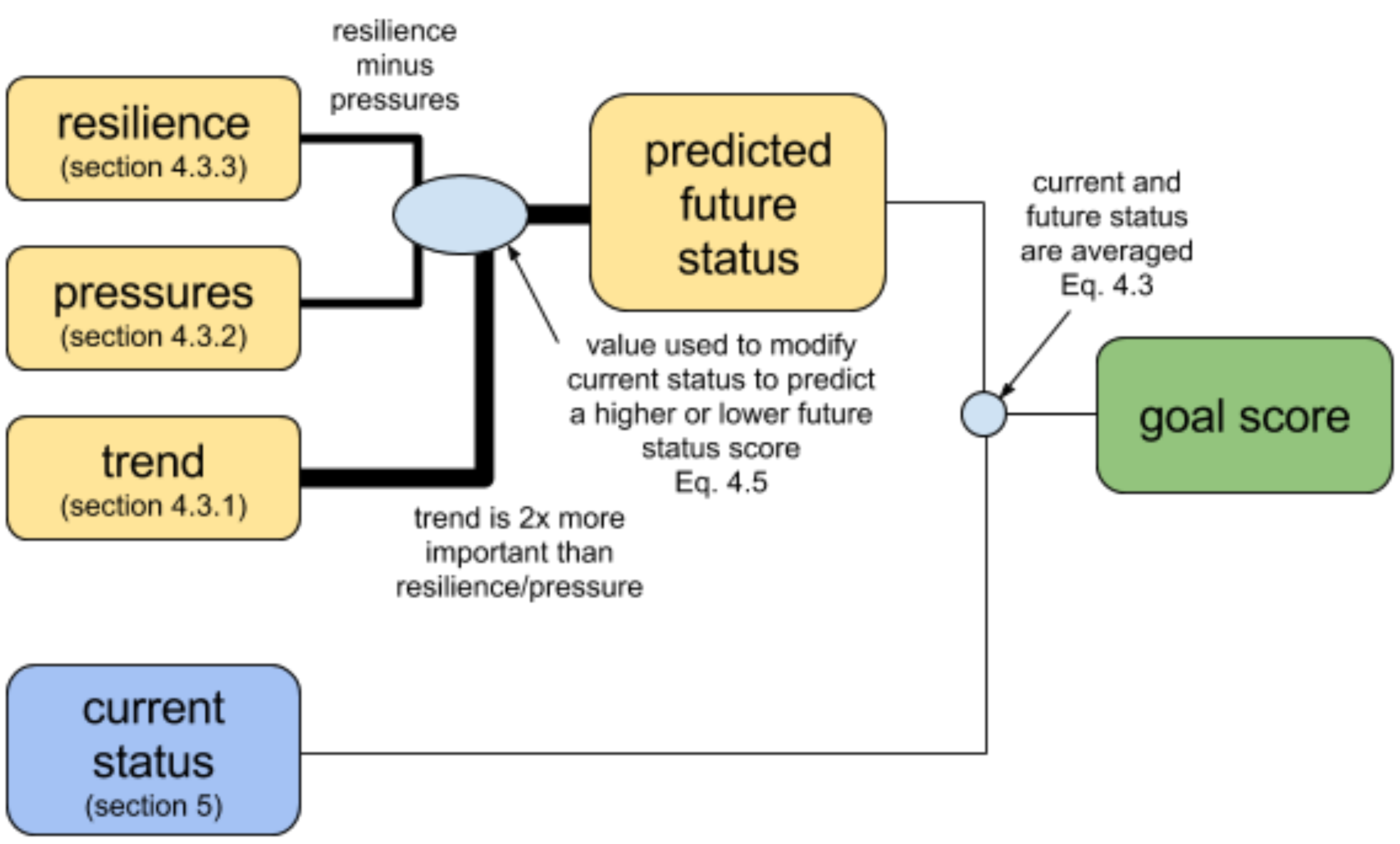
Goal (and subgoal scores) are calculated using several variables (referred to as "dimensions", Table 1.3). Goal scores (Section 4.2) are calculated as the average of current status (Section 5) and likely future status. Likely future status (Section 4.3) is the current status modified by variables (resilience, pressures, and trend) expected to influence future status.

Table 1.3. Dimension used to calculate an OHI goal score Goal scores are the average of current and likely future status. Likely future status adjusts current status scores based on pressures and resilience variables acting on the goal as well as recent trends in status.

Dimension	Subdimension	Description	More information	Calculating
Current status	-	Current state of the goal relative to the desired "reference point". Values range from	*Section 5. Goal models and data*	Calculated using functions in ohi-global repo: https://github.com/OHI-

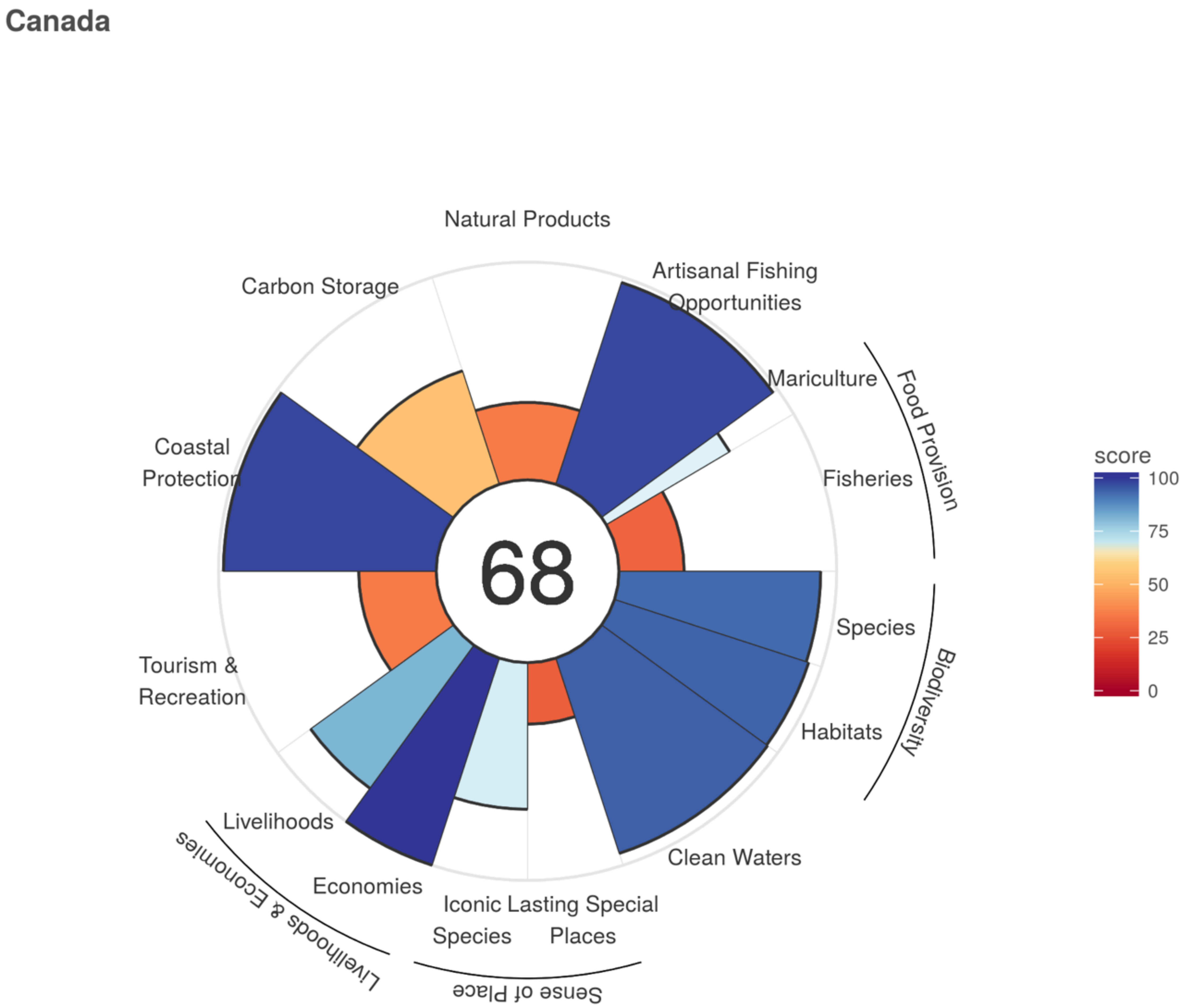
		0-100.		Science/ohi-global/blob/draft/eez/conf/functions.R (https://github.com/OHI-Science/ohi-global/blob/draft/eez/conf/functions.R) and the *scenario_data_years.csv* file (in same folder)
Predicted future status	Resilience	Variables such as good governance and ecological factors that provide resilience to pressures, and thus, are likely to improve future status. Values range from 0-100	*Section 4.3 Likely future status dimensions*	Calculated using functions in ohicore package.And, files: *resilience_categories.csv* and *resilience_matrix.csv* located here: https://github.com/OHI-Science/ohi-global/tree/draft/eez/conf (https://github.com/OHI-Science/ohi-global/tree/draft/eez/conf)
Predicted future status	Pressure	Pressures stress the system and threaten future delivery of benefits, and thus, are likely to reduce future status. Values range from 0-100	*Section 4.3 Likely future status dimensions*	Calculated using function in ohicore package. And, files: *pressure_categories.csv* and *pressures_matrix.csv*, located here: https://github.com/OHI-Science/ohi-global/tree/draft/eez/con (https://github.com/OHI-Science/ohi-global/tree/draft/eez/con)
Predicted future status	Trend	Average yearly change in status (typically estimated using most recent 5 years of data) multiplied by 5 to esimate five years into the future. Units are proportional change (absolute change/year is divided by the value of the earliest year) and range from -1 to 1	*Section 4.3 Likely future status dimensions*	Calculated using functions from ohi-global repo: https://github.com/OHI-Science/ohi-global/blob/draft/eez/conf/functions.R (https://github.com/OHI-Science/ohi-global/blob/draft/eez/conf/functions.R) and the scenario_data_years.csv file (in same folder)

Figure 1.1. Relationship between OHI dimensions and scores This figure describes how the dimensions come together to calculate a goal score. This figure represents equations 4.3 and 4.5.



Finally, an overall Index score for each region is calculated by averaging the goal scores (Figure 1.2).

Figure 1.2. Example flowerplot of goal scores for a region Goal and subgoal scores for Canada. The middle value is the regional Index score, and is calculated by averaging the goal scores.



2 Data inclusion and data gaps

Ideally, regional and local assessments should use the best available data, but this decision limits the ability to compare across scales. For direct comparisons among locations to be valid, they must use consistent data. For this reason, we focused on using global datasets so differences in Index scores across regions would be driven by differences in ocean health rather than variation in the data. Although, in reality, many global datasets are compilations of local or regional datasets and their quality varies spatially. In some cases data for a particular component or dimension of a goal were available for most but not all countries. Gaps in these data were known to not be true zero values. Rather than exclude these data layers, we employed several different methods to fill these data gaps (Frazier *et al.* 2016).

These guidelines both motivated and constrained our methods. The development of the model frameworks for each goal (including reference points) was heavily dictated by the availability of global datasets. And, ultimately, several key elements related to ocean health could not be included due to lack of existing or appropriate global datasets. As new and better data become available in the future, details of how goals or dimensions are modeled will likely change, although the framework we have developed can accommodate these changes.

For Index scores to be comparable, every region must have a value for each data layer included in the analysis, unless it is known to not be relevant to a region. In other words, missing data are not acceptable (Burgass *et al.* 2017). Adhering to this criterion is critical to avoid influencing the Index score simply because of inclusion (or absence) of a particular data layer for any reporting region.

Gaps in data are common; many developing countries lack the resources to gather detailed datasets, and even developed, data-rich countries have inevitable data gaps. We use a variety of methods to estimate missing data, including: averages of closely related groups (e.g., regions sharing ecological, spatial, political attributes; taxonomic groups; etc.), spatial or temporal interpolation (e.g., raster or time-series data), and predictive models (e.g., regression analysis, machine learning, etc.). Gapfilling is a major source of uncertainty, especially for certain goals and regions. Given how common gaps in data are, clear documentation of gapfilling is a critical step of index development because it provides a measure of the reliability of index scores.

One of the ongoing goals of the Ocean Health Index (OHI) has been to improve our approach to dealing with missing data, by quantifying the potential influence of gapfilled data on index scores, and developing effective methods of tracking, quantifying, and communicating this information (Frazier *et al.* 2016).

3 Regions

One of the first steps of conducting on OHI assessment is defining regions of interest. These can be based on political and/or ecological boundaries. The definition of a “region” varies depending on the goals and scale of the OHI assessment. For the global OHI each region is defined as the EEZ area (300 nm offshore) for all coastal countries and territories (e.g., US Virgin Islands).

There are 220 global coastal countries and territorial regions (Table 3.1). Regions are based on Exclusive Economic Zone boundaries (EEZ, Claus *et al.* 2012). However, we aggregate some EEZ regions to the level of country (e.g., Hawaii is estimated as part of the larger U.S.). We have also modified some boundaries (Halpern *et al.* 2012, 2015b). We do not estimate OHI values for disputed or unclaimed areas.

Figure 3.1. Global regions Map of the OHI regions (with color corresponding to 2018 regional index scores). Mollweide coordinate reference system is used because it accurately represents area.

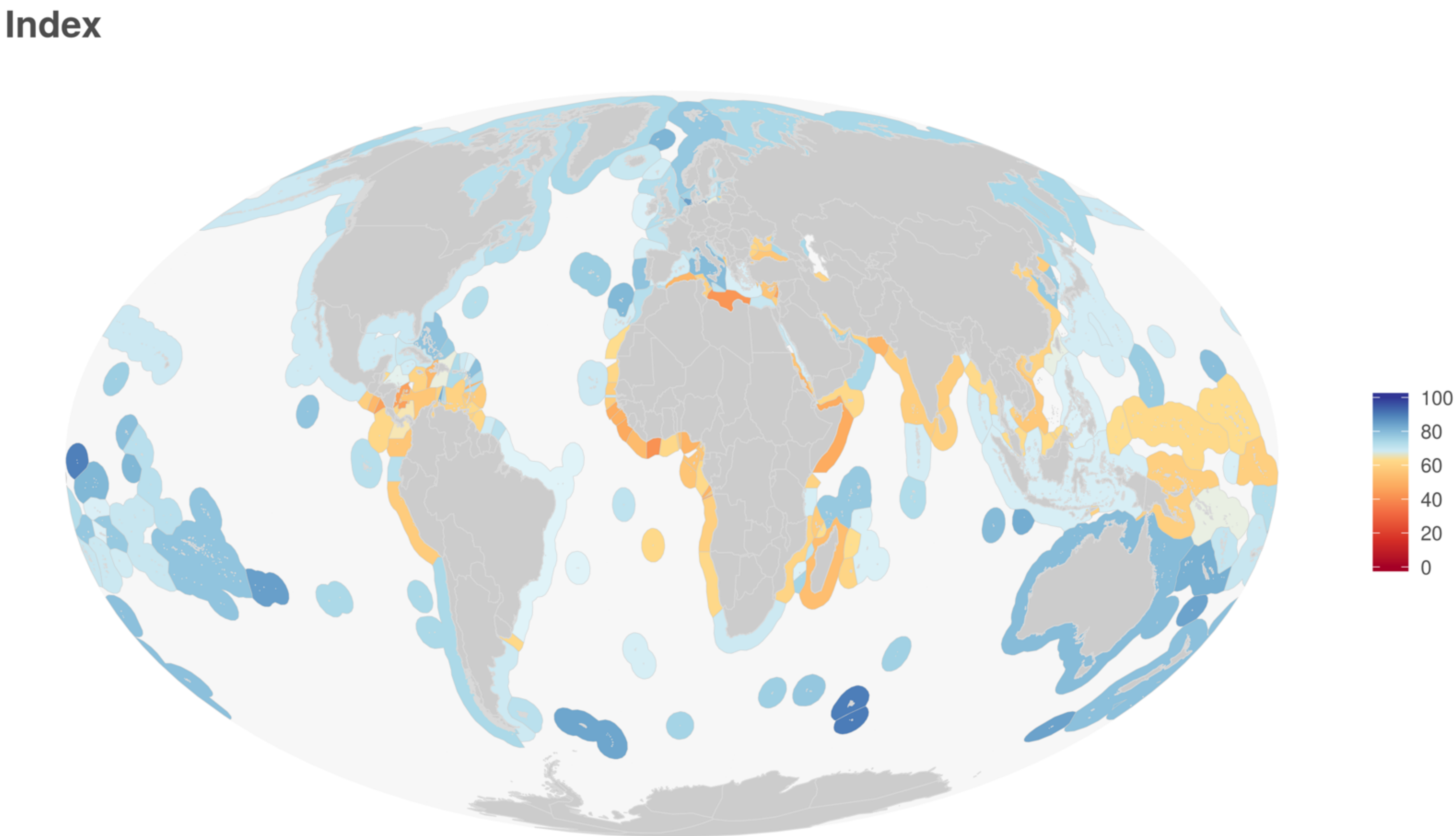


Table 3.1. Global regions

region	region ID	ISO code	type	administrative country
Albania	82	ALB	country	
Algeria	84	DZA	country	
American Samoa	151	ASM	territory	United States
Amsterdam Island and Saint Paul Island	92	ATF	territory	France
Andaman and Nicobar	26	IND	territory	India
Angola	200	AGO	country	
Anguilla	118	AIA	territory	United Kingdom
Antigua and Barbuda	120	ATG	country	
Argentina	172	ARG	country	
Aruba	250	AW	territory	Netherlands
Ascension	85	ASC	territory	United Kingdom
Australia	16	AUS	country	
Azores	55	PRT	territory	Portugal
Bahamas	110	BHS	country	
Bahrain	52	BHR	country	
Bangladesh	204	BGD	country	
Barbados	124	BRB	country	
Bassas da India	34	ATF	territory	France
Belgium	59	BEL	country	
Belize	164	BLZ	country	
Benin	99	BEN	country	

Bermuda	108	BMU	territory	United Kingdom
Bonaire	245	BQ	territory	Netherlands
Bosnia and Herzegovina	232	BIH	country	
Bouvet Island	105	BVT	territory	Norway
Brazil	171	BRA	country	
British Indian Ocean Territory	38	IOT	territory	United Kingdom
British Virgin Islands	117	VGB	territory	United Kingdom
Brunei	247	BRN	country	
Bulgaria	71	BGR	country	
Cambodia	24	KHM	country	
Cameroon	197	CMR	country	
Canada	218	CAN	country	
Canary Islands	58	ESP	territory	Spain
Cape Verde	56	CPV	country	
Cayman Islands	113	CYM	territory	United Kingdom
Chile	224	CHL	country	
China	209	CHN	country	
Christmas Island	2	CXR	territory	Australia
Clipperton Island	107	CPT	territory	France
Cocos Islands	1	CCK	territory	Australia
Colombia	132	COL	country	
Comoro Islands	28	COM	country	
Cook Islands	153	COK	territory	New Zealand
Costa Rica	130	CRI	country	
Croatia	187	HRV	country	
Crozet Islands	91	ATF	territory	France
Cuba	112	CUB	country	
Curacao	244	CW	territory	Netherlands
Cyprus	81	CYP	country	
Democratic Republic of the Congo	199	COD	country	
Denmark	175	DNK	country	
Djibouti	46	DJI	country	
Dominica	123	DMA	country	
Dominican Republic	115	DOM	country	
East Timor	231	TLS	country	
Ecuador	137	ECU	country	
Egypt	214	EGY	country	
El Salvador	134	SLV	country	
Equatorial Guinea	104	GNQ	country	
Eritrea	45	ERI	country	
Estonia	70	EST	country	
Faeroe Islands	141	FRO	territory	Denmark
Falkland Islands	95	FLK	territory	United Kingdom
Fiji	18	FJI	country	
Finland	174	FIN	country	
France	179	FRA	country	
French Guiana	169	GUF	territory	France

French Polynesia	147	PYF	territory	France
Gabon	198	GAB	country	
Gambia	65	GMB	country	
Georgia	74	GEO	country	
Germany	176	DEU	country	
Ghana	106	GHA	country	
Gibraltar	60	GIB	territory	United Kingdom
Glorioso Islands	30	ATF	territory	France
Greece	80	GRC	country	
Greenland	145	GRL	territory	Denmark
Grenada	125	GRD	country	
Guadeloupe and Martinique	140	GP-MQ	territory	France
Guatemala	136	GTM	country	
Guernsey	228	GGY	territory	United Kingdom
Guinea	194	GIN	country	
Guinea Bissau	193	GNB	country	
Guyana	167	GUY	country	
Haiti	114	HTI	country	
Heard and McDonald Islands	94	HMD	territory	Australia
Honduras	133	HND	country	
Howland Island and Baker Island	158	UMI	territory	United States
Iceland	143	ISL	country	
Ile Europa	35	ATF	territory	France
Ile Tromelin	36	ATF	territory	France
India	203	IND	country	
Indonesia	216	IDN	country	
Iran	191	IRN	country	
Iraq	192	IRQ	country	
Ireland	181	IRL	country	
Israel	79	ISR	country	
Italy	184	ITA	country	
Ivory Coast	195	CIV	country	
Jamaica	166	JAM	country	
Jan Mayen	144	SJM	territory	Norway
Japan	210	JPN	country	
Jarvis Island	149	UMI	territory	United States
Jersey	227	JEY	territory	United Kingdom
Johnston Atoll	159	UMI	territory	United States
Jordan	215	JOR	country	
Juan de Nova Island	33	ATF	territory	France
Kenya	43	KEN	country	
Kerguelen Islands	93	ATF	territory	France
Kiribati	212	KIR	country	
Kuwait	51	KWT	country	
Latvia	69	LVA	country	
Lebanon	78	LBN	country	
Liberia	97	LBR	country	

Libya	67	LBY	country	
Line Group	148	KIR	territory	Kiribati
Lithuania	189	LTU	country	
Macquarie Island	4	AUS	territory	Australia
Madagascar	42	MDG	country	
Madeira	57	PRT	territory	Portugal
Malaysia	206	MYS	country	
Maldives	39	MDV	country	
Malta	68	MLT	country	
Marshall Islands	11	MHL	country	
Mauritania	64	MRT	country	
Mauritius	37	MUS	country	
Mayotte	29	MYT	territory	France
Mexico	135	MEX	country	
Micronesia	9	FSM	country	
Monaco	185	MCO	country	
Montenegro	186	MNE	country	
Montserrat	121	MSR	territory	United Kingdom
Morocco	62	MAR	country	
Mozambique	41	MOZ	country	
Myanmar	205	MMR	country	
Namibia	101	NAM	country	
Nauru	10	NRU	country	
Netherlands	177	NLD	country	
New Caledonia	5	NCL	territory	France
New Zealand	162	NZL	country	
Nicaragua	131	NIC	country	
Nigeria	196	NGA	country	
Niue	154	NIU	territory	New Zealand
Norfolk Island	3	NFK	territory	Australia
Northern Mariana Islands and Guam	13	MNP	territory	United States
Northern Saint-Martin	221	MAF	territory	France
North Korea	21	PRK	country	
Norway	223	NOR	country	
Oecussi Ambeno	237	TLS	territory	East Timor
Oman	48	OMN	country	
Pakistan	53	PAK	country	
Palau	8	PLW	country	
Palmyra Atoll	150	UMI	territory	United States
Panama	129	PAN	country	
Papua New Guinea	17	PNG	country	
Peru	138	PER	country	
Philippines	15	PHL	country	
Phoenix Group	157	KIR	territory	Kiribati
Pitcairn	146	PCN	territory	United Kingdom
Poland	178	POL	country	
Portugal	183	PRT	country	

Prince Edward Islands	90	ZAF	territory	South Africa
Puerto Rico and Virgin Islands of the United States	116	PRI	territory	United States
Qatar	190	QAT	country	
Republique du Congo	100	COG	territory	R_publique du Congo
Reunion	32	REU	territory	France
Romania	72	ROU	country	
Russia	73	RUS	country	
Saba	248	BES	territory	Netherlands
Saint Helena	86	SHN	territory	United Kingdom
Saint Kitts and Nevis	119	KNA	country	
Saint Lucia	122	LCA	country	
Saint Pierre and Miquelon	219	SPM	territory	France
Saint Vincent and the Grenadines	127	VCT	country	
Samoa	152	WSM	country	
Sao Tome and Principe	103	STP	country	
Saudi Arabia	50	SAU	country	
Senegal	66	SEN	country	
Seychelles	31	SYC	country	
Sierra Leone	96	SLE	country	
Singapore	208	SGP	country	
Sint Eustatius	249	ANT	territory	Netherlands
Sint Maarten	220	SXM	territory	Netherlands
Slovenia	188	SVN	country	
Solomon Islands	7	SLB	country	
Somalia	44	SOM	country	
South Africa	102	ZAF	country	
South Georgia and the South Sandwich Islands	89	SGS	territory	United Kingdom
South Korea	20	KOR	country	
Spain	182	ESP	country	
Sri Lanka	40	LKA	country	
Sudan	49	SDN	country	
Suriname	168	SUR	country	
Sweden	222	SWE	country	
Syria	77	SYR	country	
Taiwan	14	TWN	country	
Tanzania	202	TZA	country	
Thailand	25	THA	country	
Togo	98	TGO	country	
Tokelau	156	TKL	territory	New Zealand
Tonga	155	TON	country	
Trinidad and Tobago	126	TTO	country	
Tristan da Cunha	88	TAA	territory	United Kingdom
Tunisia	61	TUN	country	
Turkey	76	TUR	country	
Turks and Caicos Islands	111	TCA	territory	United Kingdom
Tuvalu	19	TUV	country	
Ukraine	75	UKR	country	

United Arab Emirates	54	ARE	country	
United Kingdom	180	GBR	country	
United States	163	USA	country	
Uruguay	173	URY	country	
Vanuatu	6	VUT	country	
Venezuela	139	VEN	country	
Vietnam	207	VNM	country	
Wake Island	12	UMI	territory	United States
Wallis and Futuna	161	WLF	territory	France
Western Sahara	63	ESH	territory	Morocco
Yemen	47	YEM	country	

4 Models

4.1 Regional and global Index scores

The overall index score for each region (I_{region}) is calculated as a weighted average of all the scores (G), for each goal (g) such that:

$$I_{region} = \frac{\sum_{g=1}^{N} w_g G_g}{\sum_{g=1}^{N} w_g}, (Eq. 4.1)$$

where, w_g is the weight for each goal.

For the global assessment, the goal weights (w_g) were assumed to be equal, even though we know this assumption does not hold for most individuals or across individuals within communities. Ideally these weights would be derived empirically, but such an effort would require surveying a full spectrum of people from every single country. This was beyond the scope of this project, but may be possible in a future application of the Index.

In many places certain goals are not relevant, for example, production-focused goals typically do not apply to uninhabited islands, and the coastal protection or carbon storage goals will not apply to regions without the relevant coastal ecosystems.

The overall global index score (I_{global}) is calculated as the area weighted average of the index scores (I_{region}) for each region (i):

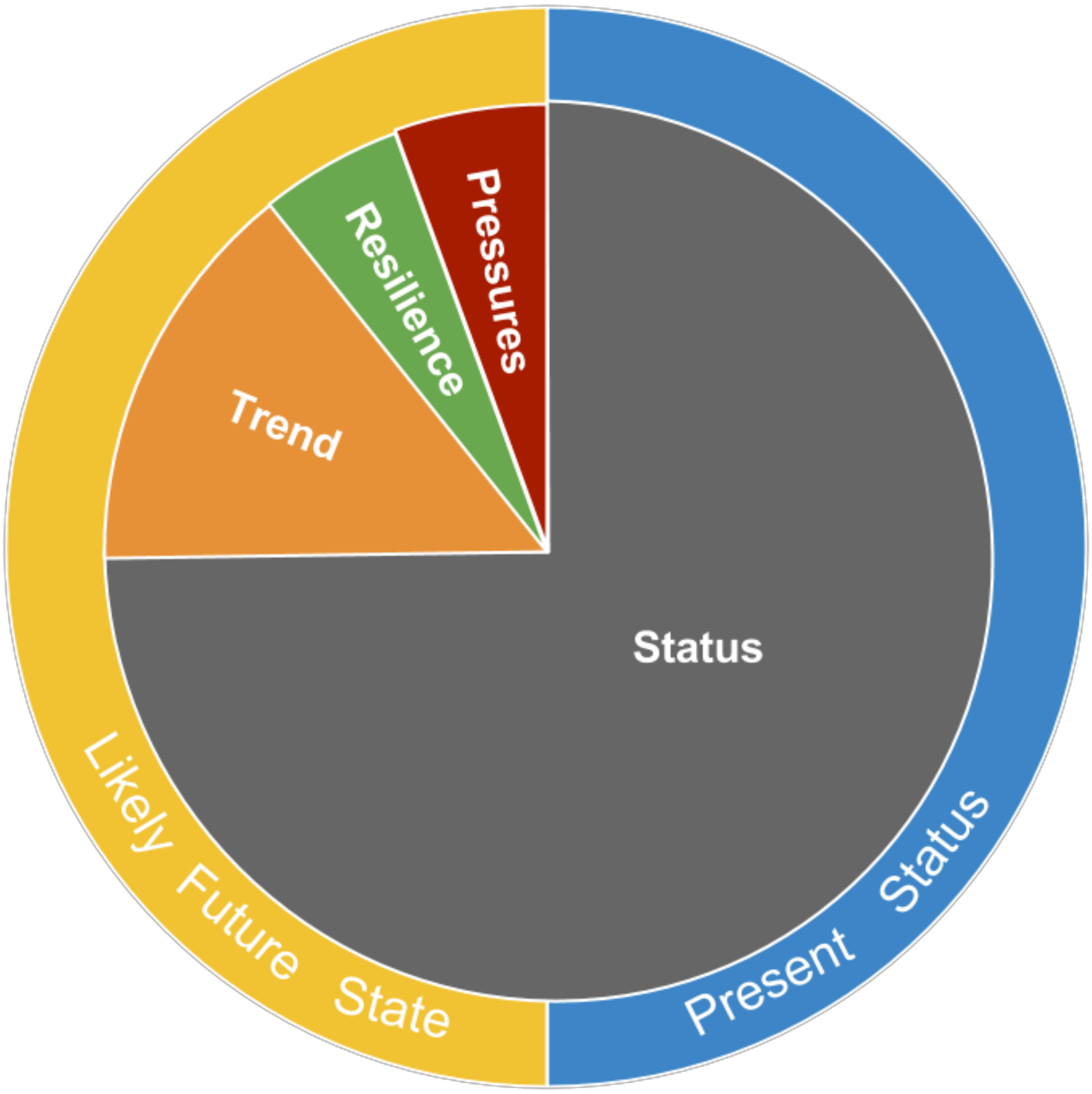
$$I_{global} = \frac{\sum_{i=1}^{N} a_i I_{region,i}}{\sum_{i=1}^{N} a_i}, (Eq. 4.2)$$

where, a_i is each region's ocean area, based on the EEZ area.

4.2 Goal scores

Each goal score is the average of its current status and likely future status (Figure 4.1, see section *5: Goal models and data* for methods used to calculate status of each goal). The Index assesses the current status of each goal relative to a reference point. Likely future status is estimated using: recent trends in current status; pressures that can stress the system and threaten future delivery of benefits; and resilience to such pressures, due to governance, institutional and ecological factors.

Figure 4.1. Pie chart describing the contribution of each dimension to the goal score



Each goal score, G, is the average of its present status, x, and its likely near-term future status, $\hat{x}_F$:

$$G = \frac{x + \hat{x}_F}{2}, (Eq. 4.3)$$

The present status of goal, x, is its present state, X, relative to a reference point, X_R, uniquely chosen for each goal:

$$x_i = \frac{X}{X_R}, (Eq. 4.4)$$

The reference point, X_R, can be determined mechanistically using a production function (e.g., maximum sustainable yield, MSY, for fisheries), spatially by means of comparison with another region (e.g., country X represents the best possible known case), temporally using a past benchmark (e.g., historical habitat extent), or in some cases via known (e.g., zero pollution) or established (e.g., 30% of waters set aside in MPAs) targets. Past benchmarks can either be a fixed point in time or a moving target (e.g., five years prior to most current data). The type of reference point can have important implications for interpretations of how a goal is doing in any given country.

For each region, the estimate of a goal's likely near-term future status is a function of its present status, x modified by: recent trends, T, in status; current cumulative pressures, p, acting on the goal; and social and ecological resilience, r, to pressures given the governance and social institutions in place to protect or regulate the system and the ecological condition of the system:

$$\hat{x}_F = [1 + \beta T + (1 - \beta)(r - p)]\, x, (Eq. 4.5)$$

where, β represents the relative importance of the trend versus the resilience and pressure terms in determining the likely trajectory of the goal status into the future. We assume $\beta = 0.67$, which makes trend twice as important as the pressure/resilience component. We chose this value because we believe the direct measure of trend is a better indicator of future (i.e., in five years) condition than indirect measures of pressure and resilience.

The role of the resilience and pressure dimensions is to improve our understanding of the likely near-term future condition by incorporating additional information beyond that provided by the recent trend. Pressure or resilience measures that were in existence in the past may have a cumulative effect that has not yet manifested itself in trend (e.g., fishing pressure may have increasingly negative impacts as successive year classes of fish become increasingly less abundant; resilience due to establishment of a marine protected area (MPA) may require a number of years before its benefits become apparent). In addition, the recent trend does not capture the effect of current levels of resilience and pressures. The expectation of a likely future condition suggested by the trend will become more or less optimistic depending on the resilience and pressure dimensions. If the effects are equal they cancel each other out.

Both resilience and pressure dimensions are scaled from 0 to 1, and trend is constrained to $-1.0 \le T \le 1.0$ (i.e., values outside this range are clamped to range end values).

The likely future status cannot exceed the maximum possible value of the status for each goal, which is 1.0. In reality data are rarely perfect, creating potential situations where likely future condition exceeds 1.0. To address these cases, we implemented two rules. First, if current status = 1.0, then trend is set = 0.0, since any trend > 0.0 in those cases must be due to incomplete or imperfect data. Second, status and likely future status scores were constrained to maximum value of 1.

4.3 Likely future status dimensions

Three dimensions are used to calculate likely future status: trends, pressure, and resilience. This section describes the calculations underlying these three dimensions.

4.3.1 Trend

Trend is the proportional change in status predicted to occur in 5 years, based on recent status data. In most cases, this is calculated by estimating the yearly change in status using a linear regression model (i.e., slope estimate) of the five most recent years of status data and multiplying this value by 5 to estimate the change five years into the future. To determine proportional change, we divide the slope estimate by the status value of the earliest year of data used in the trend calculation.

In OHI assessments prior to 2016, we calculated trend as the *absolute* change in status predicted to occur in 5 years. In 2016, we began calculating the *proportional* change by dividing the slope estimate by the status of the earliest year used in the trend calculation. Although this change rarely had a large effect on trend, or ultimate score values, this method is more consistent with how trend data is incorporated into the likely future status model (Eq. 4.5). If the β, pressure (p), and resilience (r) components of the likely future status model are ignored (this assumes the pressure and resilience components fully cancel each other out), the equation becomes:

$x(1 + trend),$

where, x is the current status. Given this, if $x = 50$, and we expect trend to increase by 10% over 5 years, then likely future status would be: $50(1 + 0.10) = 55$.

Trends indicate proportional change in status, so they typically range from -100% to +100% (or, -1.0 to +1.0), therefore we constrained values to this range.

For all goals we included the trend estimate, even if the linear model was not statistically significant (i.e., P<0.05). We chose to include these values for two key reasons: 1) we were not trying to predict the future but instead only indicate likely condition. 2) in nearly all cases we did not have sufficient data to conduct more rigorous trend analyses.

In some cases, we were not able to estimate trend using status data due to data limitations. In these cases, we used alternative methods to estimate trend. Specific details about trend calculations for each goal are provided in section 5.

We recognize several possible shortcomings in using past trends to estimate likely future status. We assume a simple linear trend, but this is not always the case due to a variety of variables such as altered pressures and resilience responses, nonlinear patterns in system response, stochastic environmental and biological variability, and simple bounding conditions (status cannot go below zero or above 1.0, and so the trend must level off as it approaches these values). Also, it is important to note that the same trend value could reflect many different processes. For example, declines due to unsustainable harvest of a resource can look identical to declines due to restrictions placed on resource users to allow the resource to recover. It also may be too short a time frame to determine true trends or the causes of those trends, but the intent here is more about informing the likely near-term trajectory.

4.3.2 Pressure

The pressure score, p, describes the cumulative pressures acting on a goal which suppress the goal score. Pressure scores range from 0 to 1, and they are calculated for each goal and region and include both ecological (p_E) and social pressures (p_S) (Table 4.1, Figure 4.2), such that:

$$p \quad = \quad \gamma * p_E \quad + \quad (1 - \gamma) * p_S, (Eq. 4.6)$$

where γ is the relative weight for ecological vs. social pressures and equals 0.5 for the global assessment. At global scales, little evidence exists to support unequal weighting of ecological and social pressures for most goals; furthermore, unequal weighting would require unique values for each goal and there is currently no empirical work to guide such decisions. At local or regional scales there may be clear evidence for unequal weights per goal and γ should be adjusted accordingly.

Figure 4.2. Pressure components Pressure is calculated using both social and ecological pressures. Ecological pressures include 5 subcategories (fishing pressure, habitat destruction, climate change, water pollution, and species/genetic introductions).

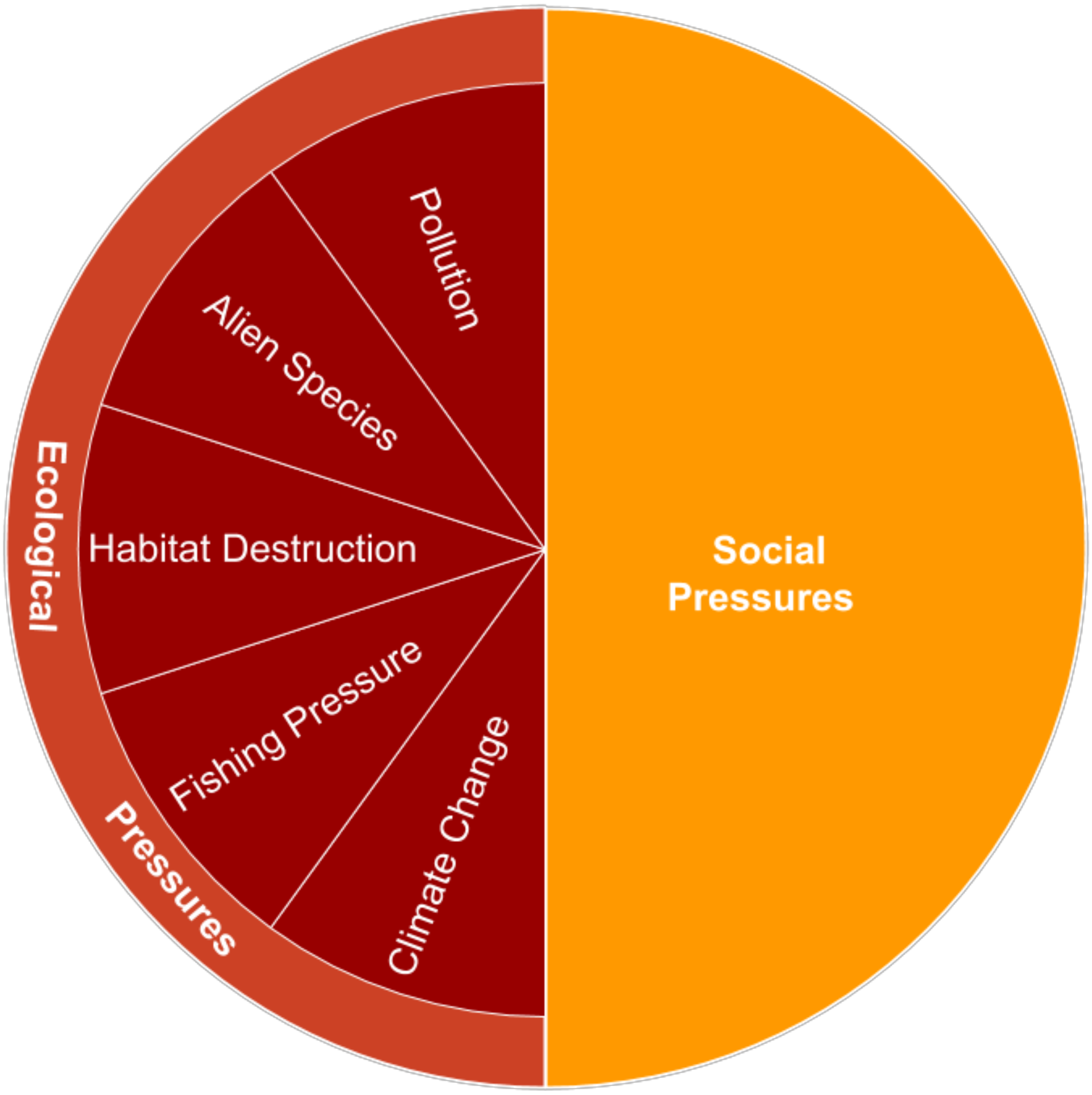


Table 4.1. Pressure data and categories Description of the stressor data layers used to calculate overall pressure for each goal and region for the global assessment (descriptions of pressure data in section 6). Each data layer is assigned to an ecological or social category, and ecological data are assigned to one of five subcategories.

Data	Short name	Category	Subcategory	Description
Chemical pollution	po_chemicals	ecological	pollution	Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)
Coastal chemical pollution	po_chemicals_3nm	ecological	pollution	Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)
Pathogen pollution	po_pathogens	ecological	pollution	Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution
Nutrient pollution	po_nutrients	ecological	pollution	Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption
Coastal nutrient pollution	po_nutrients_3nm	ecological	pollution	Modeled nutrient pollution within EEZ based on fertilizer consumption
Marine plastics	po_trash	ecological	pollution	Global marine plastic pollution
Nonindigenous species	sp_alien	ecological	alien species	Measure of harmful invasive species
Genetic escapes	sp_genetic	ecological	alien species	Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes
Subtidal soft bottom habitat destruction	hd_subtidal_sb	ecological	habitat destruction	Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)
Subtidal hardbottom habitat destruction	hd_subtidal_hb	ecological	habitat destruction	Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction
Intertidal habitat destruction	hd_intertidal	ecological	habitat destruction	Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction
High bycatch due to commercial fishing	fp_com_hb	ecological	fishing pressure	Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP
Low bycatch due to commercial fishing	fp_com_lb	ecological	fishing pressure	Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Low bycatch due to artisanal fishing	fp_art_lb	ecological	fishing pressure	Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP
High bycatch due to artisanal fishing	fp_art_hb	ecological	fishing pressure	Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP
Targeted harvest of cetaceans and marine turtles	fp_targetharvest	ecological	fishing pressure	Targeted harvest of cetaceans and marine turtles
Sea surface temperature	cc_sst	ecological	climate change	Presure due to increasing extreme sea surface temperature events
Ocean acidification	cc_acid	ecological	climate change	Pressure due to increasing ocean acidification, scaled using biological thresholds
UV radiation	cc_uv	ecological	climate change	Pressure due to increasing frequency of UV anomolies
Sea level rise	cc_slr	ecological	climate change	Pressure due to rising mean sea level
Weakness of governance	ss_wgi	social	social	Inverse of World Governance Indicators (WGI) six combined scores
Weakness of social progress	ss_spi	social	social	Inverse of Social Progress Index scores

4.3.2.1 Ecological pressure

We assessed five broad, globally-relevant categories of ecological stressors: fishing pressure, habitat destruction, climate change (including ocean acidification), water pollution, and species introductions (invasive species and genetic escapes). The five categories are intended to capture known pressures to the social-ecological system associated with each goal. Each pressure category may include several stressors. The intensity of each stressor within each OHI region is scaled from 0 to 1, with 1 indicating the highest stress (e.g., example of one of these data layers is sea surface temperature (https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/cc_sst.csv)).

We determined the rank sensitivity of each goal/subgoal to each stressor (or, when possible, an element of the goal, such as a specific habitat). We ranked ecological pressures as having ‘high’ (score = 3), ‘medium’ (score = 2), ‘low’ (score = 1), or ‘no’ (score = NA) impact (Table 4.2). Wherever possible we relied on peer-reviewed literature to establish these rankings, and relied on our collective expert judgment in cases with no available literature (Table S28 in Halpern et al. 2012). The pressure ranks are based on a rough estimate of the global average intensity and frequency of the stressor. We recognize that this will create over- and under-estimates for different places around the planet, but to address such variance in a meaningful way would require a separate weighting matrix for every single region on the planet, which is not feasible at this time.

Table 4.2. Pressure matrix Rank sensitivity of each goal (or, goal element) to each stressor.

goal	element	cc_acid	cc_slr	cc_sst	cc_uv	fp_art_hb	fp_art_lb	fp_com_hb	fp_com_lb	fp_targetharvest	hd_intertidal	hd_subtidal_hb	hd_subtidal_sb	po
AO						3		2	1		1	3	1	
CP	coral	1	2	3	1							3		
CP	mangrove		2								3			
CP	saltmarsh		3								3			
CP	seagrass	1	3	2							3			
CP	seaice shoreline		2	3										
CS	mangrove		1								3			
CS	saltmarsh		2								3			
CS	seagrass	1	2	2							3			
CW														
ECO	Aquarium Trade Fishing	1		1		3	1					3		2
ECO	Commercial Fishing					2	1	3	1		1	2	2	2
ECO	Mariculture		1											2
ECO	Marine Mammal Watching							1						
ECO	Tourism		2											3
ECO	Wave & Tidal Energy		1											
FIS						2	1	3	1		1	2	2	1

HAB	coral	1	1	3	1	3						3		
HAB	mangrove		1								3			
HAB	saltmarsh		2								3			
HAB	seagrass	1	2	2							3			
HAB	seaice edge		1	3										
HAB	soft bottom						1	3	1				3	
ICO		1		1		2		2		2	3	2		
LIV	Commercial Fishing					2	1	3	1		1	2	2	2
LIV	Mariculture		1											2
LIV	Marine Mammal Watching							1						
LIV	Ports & Harbors		2											
LIV	Ship & Boat Building													
LIV	Tourism		2											3
LIV	Transportation & Shipping													
LIV	Wave & Tidal Energy		1											
LSP			1								3	2		
MAR			1											2
NP	corals	1	1	3	1							3		1
NP	fish oil			1					2				2	2
NP	ornamentals			1		3	1					3		2
NP	seaweeds			1							1			2
NP	shells	1		1							1		2	
NP	sponges	1		1		1							3	
SPP		1		1	1	2	1	3	1	1	2	2	3	2
TR			2											

To estimate the cumulative effect of the ecological pressures, P_E, we first determined the cumulative pressure, p, within each ecological category, i (e.g., pollution, fishing, etc.):

$$p_i = \frac{\sum_{i=1}^{N} w_i s_i}{3}, (Eq. 4.7)$$

Where w_i is the sensitivity ranks (Table 4.2) describing the relative sensitivity of each goal to each stressor, and s_i is intensity of the stressor in each region on a scale of 0-1. We divided by the maximum weighted intensity that could be achieved by the worst stressor (max = 3.0).

If $p_i > 1.0$, we set the value equal to 1.0. This formulation assumes that any cumulative pressure load greater than the maximum intensity of the worst stressor is equivalent to maximum stressor intensity.

For the goals for which sensitivity ranks were assigned for specific habitats or livelihood sectors (i.e., goal elements), we calculated the weighted sum of the pressures for only those habitats or sectors that were present in the country.

The overall ecological pressure, p_E, acting on each goal and region was calculated as the weighted-average of the pressure scores, p, for each category, i, with weights set as the maximum rank in each pressure category (w_{i_max}) for each goal, such that:

$$p_E = \frac{\sum_{i=1}^{N} (w_{i\_max} * p_i)}{\sum_{i=1}^{N} w_{i\_max}}, (Eq. 4.8)$$

Stressors that have no impact drop out rather than being assigned a rank of zero, which would affect the average score.

4.3.2.2 Social pressures

Social pressures describe the lack of effectiveness of government and social institutions. Social stressors are described for each region on a scale of 0 to 1 (with one indicating the highest pressure). Social pressure is then calculated as the average of the social stressors:

$$p_S = \frac{\sum_{i=1}^{N} z_i}{N}, (Eq. 4.9)$$

where z_i are the social pressure measures specific to the goal. Unequal weighting may be appropriate in some cases but is difficult to assess currently, particularly at the global scale.

4.3.2.3 Caveats

There were a number of ecological pressures not included in our assessment, including altered sediment regimes, noise and light pollution, toxic chemicals from point sources, nutrient pollution from atmospheric deposition and land-based sources other than fertilizer application to agricultural land. In all cases, global data do not exist in a format that would allow for adequate comparisons within and among countries. Future global or regional iterations of the Index could include these data as they become available.

The calculation of ecological pressures is sensitive to the number of stressors within each category (but not to the number of categories). Inclusion of additional stressors within categories would require careful calibration of ranks so that the cumulative effect of a larger number of stressors does not overestimate pressure.

A key assumption in our assessment of ecological pressures is that each goal has a linear and additive response to increases in intensity of the stressors. Clearly many ecosystems respond non-linearly to increased stressor intensity, exhibiting threshold responses, and there are likely nonlinear interactions among stressors. Unfortunately little is known about the nature of these types of nonlinearities and interactions so we could not include them in any meaningful way.

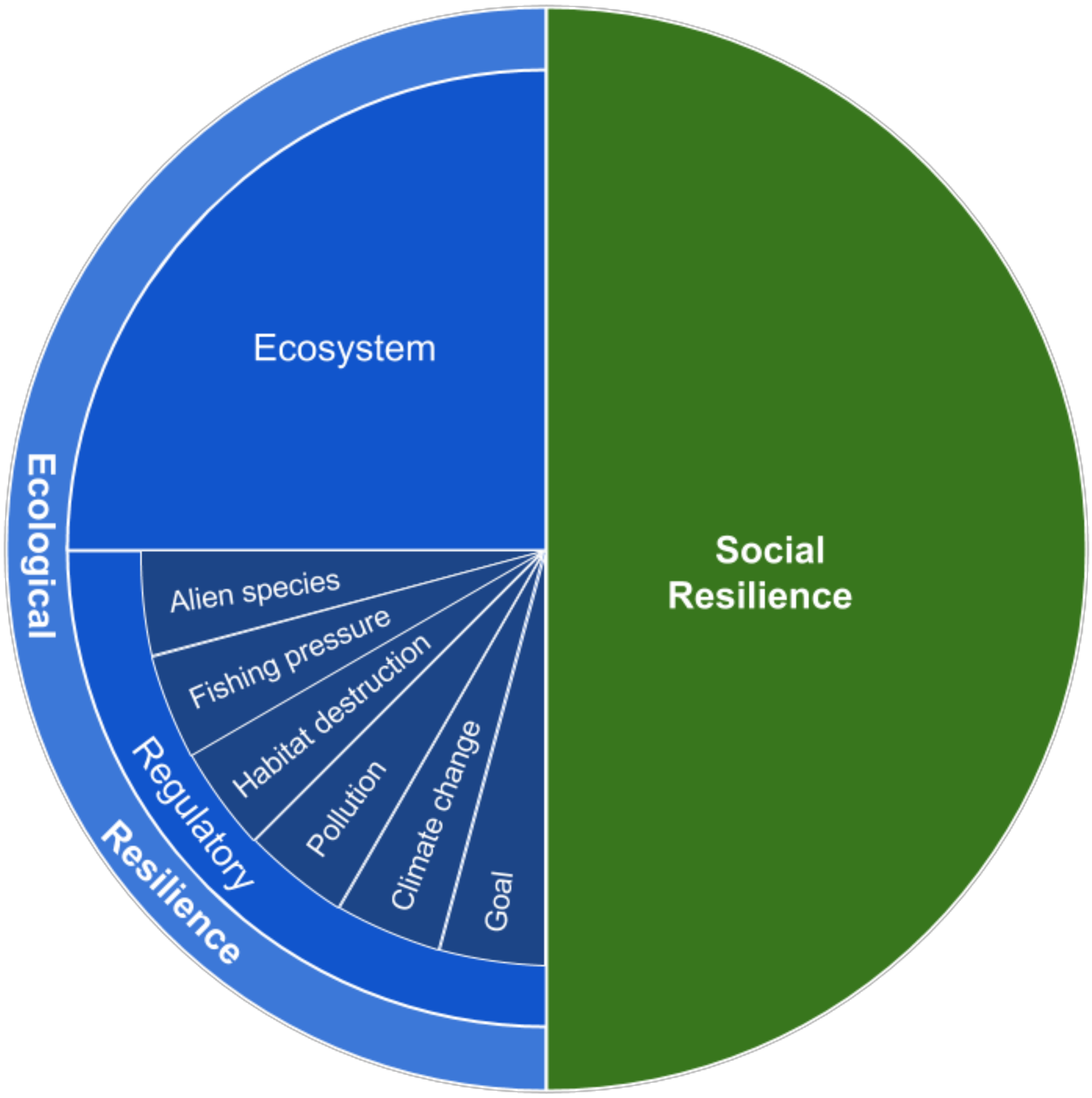
4.3.3 Resilience

To calculate resilience for each goal and region, r, we assess three resilience categories (Table 4.3, Figure 4.3): ecological integrity, Y_E, regulatory efforts that address ecological pressures, Y_R, and social integrity, Y_S. The first two measures address ecological resilience while the third addresses social resilience. When all three aspects are relevant to a goal, resilience is calculated as:

$$r = \gamma * (\frac{Y_E + Y_R}{2}) + (1 - \gamma) * Y_S, (Eq. 4.10)$$

We chose $\gamma = 0.5$ so the weight of resilience components that address ecological systems (ecosystem and regulatory) vs. social systems would be equivalent to the proportions used in the model to calculate pressure.

Figure 4.3. Resilience components Resilience includes both ecological and social resilience categories. Ecological resilience includes an ecosystem and regulatory category. The regulatory category includes 5 subcategories that mirror the pressure categories (fishing pressure, habitat destruction, climate change, water pollution, and species/genetic introductions) as well as a goal-specific category.



Each resilience category is composed of 1 or more data layers (Table 4.3) with values scaled from 0-1, reflecting the magnitude of resilience, for each region (an example of one of these data layers describes tourism regulations that preserve biodiversity (https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/g_tourism.csv)). Each resilience data layer is assigned a weight of 0.5 or 1 (Table 4.3) that is applied equally across all the goals (or, goal elements) influenced by the resilience layer (i.e., resilience matrix, Table 4.4). This information is used to calculate a score for each resilience category. The weight reflects information about governance.

Table 4.3. Resilience categories and weights The data layers used to calculate resilience for each goal and region for the global assessment (descriptions of data layers and sources are in section 6). Each data layer is assigned to an ecological or social category. The ecological category is broken into an ecosystem and regulatory category type.

Data	Short name	Category	Category type	Subcategory	Weight
Measure of ecological integrity	species_diversity_eez	ecological	ecosystem	ecological	1.0
Measure of coastal ecological integrity	species_diversity_3nm	ecological	ecosystem	ecological	1.0
Management of nonindigenous species	sp_alien_species	ecological	regulatory	alien species	1.0
CITES signatories	g_cites	ecological	regulatory	goal	0.5
Coastal protected marine areas (fishing preservation)	fp_mpa_coast	ecological	regulatory	fishing pressure	1.0
EEZ protected marine areas (fishing preservation)	fp_mpa_eez	ecological	regulatory	fishing pressure	1.0
Management of habitat to protect fisheries biodiversity	fp_habitat	ecological	regulatory	fishing pressure	1.0
Commercial fishing management	fp_mora	ecological	regulatory	fishing pressure	1.0
Artisanal fisheries management effectiveness	fp_mora_artisanal	ecological	regulatory	fishing pressure	1.0
Management of habitat to protect habitat biodiversity	hd_habitat	ecological	regulatory	habitat destruction	1.0
Coastal protected marine areas (habitat preservation)	hd_mpa_coast	ecological	regulatory	habitat destruction	1.0
EEZ protected marine areas (habitat preservation)	hd_mpa_eez	ecological	regulatory	habitat destruction	1.0
Management of mariculture to preserve biodiversity	g_mariculture	ecological	regulatory	goal	1.0
Mariculture Sustainability Index	g_msi_gov	ecological	regulatory	goal	1.0
Management of tourism to preserve biodiversity	g_tourism	ecological	regulatory	goal	1.0
Management of waters to preserve biodiversity	po_water	ecological	regulatory	pollution	1.0
Global Competitiveness Index (GCI)	li_gci	social	social	social	1.0
Economic diversity	li_sector_evenness	social	social	social	1.0
Strength of governance	wgi_all	social	social	social	1.0
Social Progress Index	res_spi	social	social	social	1.0

Table 4.4. Resilience matrix Describes which goals/subgoals (and goal elements) are influenced by the resilience data layers.

goal	element	po_water	hd_mpa_coast	hd_mpa_eez	hd_habitat	sp_alien_species	fp_mpa_coast	fp_mpa_eez	fp_habitat	fp_mora	fp_mora_artisanal	g
AO			x		x		x		x	x		
CP	coral	x	x		x							
CP	mangrove		x		x							
CP	saltmarsh	x	x		x							
CP	seagrass	x	x		x							
CP	seaice_shoreline											
CS	mangrove		x		x							
CS	saltmarsh	x	x		x							
CS	seagrass	x	x		x							
CW		x										
ECO												
FIS				x	x			x	x	x	x	
HAB	coral	x	x		x		x		x		x	x
HAB	mangrove		x		x							x
HAB	saltmarsh	x	x		x							x
HAB	seagrass	x	x		x							x
HAB	seaice_edge											x
HAB	soft_bottom	x		x	x			x	x	x		x

ICO		x		x	x		x	x	x	x	
SPP		x		x	x		x	x	x	x	x
LIV											
LSP		x			x						
MAR		x									
NP	corals	x	x		x						
NP	fish_oil	x		x	x		x	x	x		
NP	ornamentals	x	x		x	x		x		x	
NP	seaweeds	x									
NP	shells		x		x						
NP	sponges		x		x						
TR		x									

4.3.3.1 Ecological resilience

4.3.3.1.1 Ecosystem integrity

Ecosystem integrity, e.g., food web integrity, is measured as relative condition of assessed species in a given location (scores from the species subgoal were used to estimate ecosystem integrity). For some goals, there is little evidence that our index of ecosystem integrity directly affects the value of the goal (or subgoal). In these instances, ecological integrity falls out of the resilience model.

For the global assessments, we only have one data layer describing ecosystem integrity, however, if there were multiple layers the overall score for ecosystem integrity would be a weighted mean of all the data layers, i, that describe ecosystem integrity ($y_{E,i}$) and influence the goal:

$$Y_E = \frac{\sum_{i=1}^{N} w_i y_{E\,i}}{\sum_{i=1}^{N} w_i}, (Eq. 4.11)$$

4.3.3.1.2 Regulatory resilience

Regulatory resilience (Y_R) describes the institutional measures (e.g., rules, regulations, and laws) designed to address ecological pressures. The regulatory resilience datasets are grouped into five categories that address the 5 pressure categories: fishing pressure, habitat destruction, climate change (including ocean acidification), water pollution, and species introductions (invasive species and genetic escapes). There is also an additional category for goal-specific regulations that apply to a goal or goals, but do not address a larger pressure category.

Weights were based effectiveness of governance. Governance is a function of 1) institutional structures that address the intended objective, 2) a clear process for implementing the institution is in place, and 3) whether the institution has been effective at meeting stated objectives. At global scales it is very difficult to assess these three elements; we usually only had information on whether institutions exist. However, in some cases we had detailed information on institutions that enabled us to assess whether they would contribute to effective management, and thus, increased ocean health. In those latter cases, we gave more weight to those measures (Table 4.3).

For each region and goal, we calculated a score for each regulatory category, $y_{R,i}$, as a weighted mean of the resilience data layers, r_i, that influence the goal (Table 4.4):

$$y_{R,i} = \frac{\sum_{i=1}^{N} w_i r_i}{\sum_{i=1}^{N} w_i}, (Eq. 4.12)$$

where, w_i is the weight in Table 4.3.

To calculate the overall regulatory resilience, Y_R, we averaged the scores for each regulatory category.

4.3.3.2 Social integrity resilience

Social integrity is intended to describe those processes internal to a community that affect its resilience. It is a function of a wide range of aspects of social structure. Social Integrity per goal for each region, Y_S, is therefore:

$$Y_S = \frac{\sum_{i=1}^{N} y_{S,i}}{N}, (Eq. 4.13)$$

where $y_{S,i}$ are the social integrity measures specific to the goal.

Ideally, assessments of social resilience would include state and federal level rules and other relevant institutional mechanisms as well. However, such information is extremely difficult to access for every single country, and so we relied on global datasets that focus on international treaties and assessments. Another key gap is information on social norms and community (and other local-scale) institutions (such as tenure or use rights) that influence resource use and management in many settings. Information on these institutions is also extremely difficult to find at a global scale, although the World Governance Indicator (Kaufmann *et al.* 2010) partly measures their effectiveness through its inclusion of corruption indices.

5 Goal models and data

In this section we describe how the current status and trend of each goal was calculated. We also indicate which data layers were used to calculate current status, trend (if different from current status), pressure, and resilience.

The R code used to calculate the goal model is located here (https://github.com/OHI-Science/ohi-global/blob/draft/eez/conf/functions.R) (scroll to the appropriate goal function). To learn more about the data layers used in the model calculations see Section 6: Description of data layers. Table 6.1 includes links to the code and data used to create the data layers (current calculations are in the folder with the most recent year). Table 6.2 describes the data sources used to create the data layers.

5.1 Artisanal opportunities

Artisanal fishing, often also called small-scale fishing, provides a critical source of food, nutrition, poverty alleviation and livelihood opportunities for many people around the world, in particular in developing nations (Allison & Ellis 2001). Artisanal fishing refers to fisheries involving households, cooperatives or small firms (as opposed to large, commercial companies) that use relatively small amounts of capital and energy and small fishing vessels (if any), make relatively short fishing trips, and use fish mainly for local consumption or trade. These traits differ from commercial scale fisheries that serve the global fish trade, and commercial and artisanal scale fisheries also differ in how they are valued by many communities around the world.

Artisanal fisheries contribute over half of the world's marine and inland fish catch, nearly all of which is used for direct human consumption (United Nations 2010). They employ over 90 percent of the world's more than 35 million capture fishers and support another approximate 90 million people employed in jobs associated with fish processing, distribution and marketing (United Nations 2010). Artisanal fisheries also are distinguished by the role they play in shaping and sustaining human cultures around the world; this role contributes to their distinct value (McGoodwin 2001). For this reason, we designate artisanal fishing opportunities as a distinct public goal. In some countries like the U.S.A., artisanal fishing may happen under a commercial license (e.g., a family run lobster boat or individual shellfish harvesting permit), or under a recreational fishing permit (e.g., families fishing with rods for fish to eat); the food provided by these activities should ideally be captured under the food provision goal, whereas the opportunity to pursue artisanal fishing is captured here. The goal is not about recreational fishing for sport, which is captured in food provision (if it provides food) and tourism and recreation.

The livelihood and household economy provided by fishing are considered part of the coastal livelihoods and economies goal, although similar to food provision from artisanal fishing it is currently impossible to measure on a global scale. Our focus is on the opportunity to conduct this kind of fishing. What is intended by the idea of 'opportunity' is the ability to conduct sustainable artisanal-scale fishing when the need is present, rather than the actual amount of catch or household revenue that is generated. Although this may seem nuanced on the value and intent of artisanal fishing, the opportunity to conduct this fishing is clearly of great importance to many people (McGoodwin 2001). Status for this goal is a function of need for artisanal fishing opportunities and whether or not the opportunity is permitted and/or encouraged institutionally and done sustainability. This need could potentially be driven by any number of socio-economic factors, but perhaps the simplest and most directly tied to this need is the percent of the population that is below the poverty level. Data on how many people live below the poverty level are not available for many countries. Therefore, we used an analogous proxy that is more complete globally: per capita gross domestic product (pcGDP) adjusted by the purchasing power parity (PPP). This metric translates the average annual income (pcGDP) into its local value (PPP). These data correlate with UN data on the percent of a population living below the $2/day international poverty standard (linear: $R^2 = 0.61$, $p < 0.001$; logarithmic regression: $R^2 = 0.76$, $p < 0.001$). Because the relationship is a better fit with the ln-linear regression, we ln-transform the PPPpcGDP scores.

5.1.0.1 Current status

Status for this goal (x_{ao}) is therefore measured by unmet demand (D_u), which includes measures of opportunity for artisanal fishing (O_{ao}, defined below) and the sustainability of the methods used (S_{ao}):

$$x_{ao} = (1 - D_u) * S_{ao}, (Eq. 5.1)$$

where S_{ao} indicates whether artisanal fishing is done in a sustainable manner, and is set to 1 because no data or information exist globally on the proportion of fishermen using sustainable versus unsustainable gear, S_{ao}. And, D_u is calculated as:

$$D_u = (1 - PPPpcGDP) * (1 - O_{ao}), (Eq. 5.2)$$

where, $PPPpcGDP$ is the ln-transformed, rescaled purchasing power parity adjusted per capita GDP, and O_{ao} is the access to artisanal-scale fishing determined by Mora et al. (2009).

We rescaled the ln-transformed $PPPpcGDP$ values from 0-1 by dividing by the value corresponding to the 99th quantile across all regions and years from 2005 to 2015 (values > 1 were capped at 1). Developed countries with lower demand for artisanal scale fishing (i.e., low poverty indicated by high PPPpcGDP) score high, regardless of the opportunity made available (since it would not matter to many), and developing countries with high demand and opportunity would also score high.

To assess the opportunity or ability to meet this demand, O_{ao}, we used data from Mora et al. (2009), which scores countries on the institutional measures that support or facilitate artisanal and small-scale fishing. The data come from Figure S4 in Mora et al. (2009), which is based on two survey questions focused on recreational and artisanal fishing (Table 5.1) and are on a scale from 0 to 100 (which we then rescale 0-1), where higher scores indicate better management. We extracted the data from the color codes on the map in Figure S4 in Mora et al. (2009). There may be some small errors far a few countries due to difficulty of distinguishing between the two red colors at the lowest end of the scale.

The sustainability of artisanal fishing practices could be approximated by the percent of fishermen that use sustainable gear such as hook and line versus unsustainable methods such as dynamite, cyanide and, arguably, gill net fishing. Unfortunately data on proportion of gear type used within a country is scarce at best and so we were unable to include this term in the calculation of this goal; we present it here for conceptual completeness. We considered using the information and data contained in Pitcher et al. (2006) which looks at compliance of 53 countries with the UN's Code of Conduct for responsible fisheries. These results are strongly correlated with the data from Mora et al. (2009) ($p < 0.001$; $R^2 = 0.22$), and thus we used the Mora et al.

Several issues and datasets relevant to artisanal fishing opportunities were not included in our calculations for a number of reasons. High unemployment can lead to a greater demand for artisanal fishing opportunities (Cinner *et al.* 2009), but unemployment is not a good measure of potential 'demand' for most developing countries since many people not working do not get recorded in unemployment statistics, even though it may be relevant for developed countries. Regardless, it is very difficult to set an arbitrary cut-off for developing versus developed countries, and so there is no clear way to use unemployment data for this goal.

Another potential driver of demand for artisanal fishing opportunities is local preference for seafood and/or access to other sources of protein. Previous analyses have shown that seafood consumption (a proxy for preference for seafood) does not correlate well with national-level artisanal catch statistics (Halpern *et al.* 2008) and access to other sources of protein is difficult to measure, and so we did not use either of these measures here.

Table 5.1. Artisanal access. Questions from Mora et al. (2009) that were used to evaluate access to artisanal scale fishing.

- If recreational fishing exists to any extent, which of the following apply?
  - Are recreational fishermen required to have a fishing license?
  - Are there regulations to the size of fish caught?
  - Are there regulations to the number of fish caught?
  - Are there regulations to the number of fishermen allowed to fish?
  - Are there statistics being collected for this sort of fishing? *If artisanal fishing exists to any extent, which of the following apply?
  - Are there regulations to the size of fish caught?
  - Are there regulations to the number of fish caught?
  - Are there regulations to the number of fishermen allowed to fish?
  - Are there statistics being collected for this sort of fishing?

5.1.0.2 Trend

Trend was calculated as described in section 4.3.1. Because we only have one value for O_{ao}, the trend becomes the change over time in the PPPpcGDP, i.e., how 'unmet demand' is changing over time.

5.1.0.3 Data

Status and trend

Artisanal fisheries opportunity (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_opportunity) (ao_access): The opportunity for artisanal and recreational fishing based on the quality of management of the small-scale fishing sector

Economic need for artisanal fishing (http://ohi-science.org/ohi-global/layers.html#economic_need_for_artisanal_fishing) (ao_need): Inverse of per capita purchasing power parity (PPP) adjusted gross domestic product (GDP): GDPpcPPP as a proxy for subsistence fishing need

Pressure

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Coastal protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(fishing_preservation)) (fp_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(habitat_preservation)) (hd_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Measure of coastal ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_coastal_ecological_integrity) (species_diversity_3nm): Marine species condition (same calculation and data as the species subgoal status score) calculated within 3 nm of shoreline as a proxy for ecological integrity

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.2 Biodiversity

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. For the species sub-goal, we used species risk assessments from the International Union for Conservation of Nature (IUCN 2016) for a wide range of taxa to provide a geographic snapshot of how total marine biodiversity is faring, even though it is a very small sub-sample of overall species diversity (Mora *et al.* 2011). We calculate each of these subgoals separately and weight them equally when calculating the overall goal score.

5.2.1 Habitat (subgoal of biodiversity)

The habitat subgoal measures the average condition of marine habitats present in each region that provide critical habitat for a broad range of species (mangroves, coral reefs, seagrass beds, salt marshes, sea ice edge, and subtidal soft bottom). This subgoal is considered a proxy for the condition of the broad suite of marine species.

Data availability remains a major challenge for species and habitat assessments. We compiled and analyzed the best available data in both cases, but key gaps remain. Although several efforts have been made in recent years to create or compile the data necessary to look at the status and trends of marine habitats, most efforts are still hampered by limited geographical and temporal sampling (Joppa *et al.* 2016), although mangroves (Giri *et al.* 2011) and sea ice (Cavalieri *et al.* 1996) data are exceptions. In addition, most marine habitats have only been monitored since the late 1970s at the earliest, many sites were only sampled over a short period of time, and very few sites were monitored before the late 1990s so establishing reference points was difficult. Salt marshes and seagrasses were the most data-limited of the habitats included in the analysis.

5.2.1.1 Current status

The status of the habitat sub-goal, x_{hab}, was assessed as the average of the condition estimates, C, for each habitat, k, present in a region; measured as the loss of habitat and/or % degradation of remaining habitat, such that:

$$x_{hab} = \frac{\sum_{k=1}^{N} C_k}{N}, \qquad (Eq. 5.3)$$

where, $C_k = C_c/C_r$ and N is the number of habitats in a region. C_c is the current condition and C_r is the reference condition specific to each k habitat present in the region (Table 5.2). This formulation ensures that each country is assessed only for those habitats that can exist (e.g., Canada is not assessed on the status of its nonexistent coral reefs). We generally considered the reference years to be between 1980-1995, although these varied by habitat due to data availability.

Table 5.2. Habitat data Description of condition, extent, and trend calculations for habitat data (Note: extent is not used to calculate the habitat subgoal, but is used for the coastal protection and carbon storage goals). More information about the sources used to generate these values is located in Section 6 and Table 6.1.

Habitat	Condition	Extent	Trend
Seagrass	Current % cover or hectares of habitat divided by reference % cover or hectares	Seagrass extent per oceanic region (vector based)	Calculated across data from 1975-2010
Coral reefs	Current % cover divided by reference % cover	Coral reef extent per oceanic region (500 m resolution)	Calculated across data from 1975-2006
Mangroves	Current hectares divided by reference hectares, for coastal mangroves only	Mangrove extent per oceanic region (raster based)	Calculated using 5 most recent years of data
Salt marsh	Increasing or stable trend assigned condition = 1.0; decreasing trend assigned condition = 0.5	Salt marsh extent per oceanic region	Categorical trend assessments (increasing = 0.5, stable = 0, or decreasing = -0.5)
Sea ice edge	Current (3-year rolling-average using the current year and previous 2 years) % cover of sea ice having 10-50% cover, divided by reference % cover average from 1979-2000	Same as condition	Calculated from the fitted slope of %-deviation-from-reference per year, of the most recent 5 years of data (each year of data is based on 3-year average)
Soft bottom	Soft-bottom destructive fishing practices relative to area of soft-bottom habitat and rescaled to 0-1 based on relative global values	Halpern et al. (2008)	Calculated using 5 most recent years of condition data

A significant amount of pre-processing of the habitat data was needed to fill data gaps and resolve data quality issues (Section 6). Because consistent habitat monitoring data was unavailable for many countries, anomalous values can occur. This is particularly true for highly variable habitats like seagrasses or coral reefs which can have significant site-to-site and year-to-year differences in extent and condition (Orth *et al.* 2006; Bruno & Selig 2007). Biases may also have been introduced from spatial (e.g., protected or impacted sites) and temporal (e.g., directly after a disturbance event) selections in sampling. In regions where we had a limited number of surveys in a particular country, overall status can be under- or overestimated because of these fluctuations.

5.2.1.2 Trend

Trend in habitat data were calculated as the linear trend in extent or condition with slight variations depending on habitat type. Coral reef habitat trends were calculated on a per country basis, using all available data. For seagrasses we calculated trends on a per site basis. For mangroves we used the rate of change in areal extent over the most recent 5 years of available data. For sea ice we calculated the slope across the most recent 5 years of data, where each year of data is based on a three-year moving averages to smooth out potential climate variation. For soft bottom habitat we simply calculated the slope of the recent change in condition over the past five years, i.e., the change in proportion of catch from trawl fishing per unit area of habitat within a region.

5.2.1.3 Data

Status and trend

Habitat condition of coral (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_coral) (hab_coral_health): Current condition of coral habitat relative to historical condition

Habitat condition trend of coral (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_coral) (hab_coral_trend): Estimated trend in coral condition

Habitat condition of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_mangrove) (hab_mangrove_health): Current condition of mangrove habitat relative to historical condition

Habitat condition trend of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_mangrove) (hab_mangrove_trend): Estimated trend in mangrove condition

Habitat condition of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_saltmarsh) (hab_saltmarsh_health): Current condition of saltmarsh habitat relative to historical condition

Habitat condition trend of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_saltmarsh) (hab_saltmarsh_trend): Estimated trend in saltmarsh condition

Habitat condition of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_seagrass) (hab_seagrass_health): Current condition of seagrass habitat relative to historical condition

Habitat condition trend of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_seagrass) (hab_seagrass_trend): Estimated trend in seagrass condition

Habitat condition of seaice (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_seaice) (hab_seaice_health): Current condition of seaice habitat relative to historical condition

Habitat condition trend of seaice (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_seaice) (hab_seaice_trend): Estimated trend in seaice condition

Habitat condition of softbottom (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_softbottom) (hab_softbottom_health): Current condition of softbottom habitat, based on demersal destructive fishing practices (e.g., trawling)

Habitat condition trend of softbottom (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_softbottom) (hab_softbottom_trend): Estimated change in softbottom condition, based on trends in demersal destructive fishing practices (e.g., trawling)

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

UV radiation (http://ohi-science.org/ohi-global/layers.html#uv_radiation) (cc_uv): Pressure due to increasing frequency of UV anomolies

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_management_effectiveness) (fp_mora_artisanal): Quality of management of small-scale fishing for artisanal and recreational purposes

Coastal protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(fishing_preservation)) (fp_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(fishing_preservation)) (fp_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of mariculture to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_mariculture__to_preserve_biodiversity) (g_mariculture): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: mariculture related questions

Management of tourism to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_tourism_to_preserve_biodiversity) (g_tourism): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: tourism related questions

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(habitat_preservation)) (hd_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(habitat_preservation)) (hd_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Measure of coastal ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_coastal_ecological_integrity) (species_diversity_3nm): Marine species condition (same calculation and data as the species subgoal status score) calculated within 3 nm of shoreline as a proxy for ecological integrity

Measure of ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_ecological_integrity) (species_diversity_eez): Marine species condition (species subgoal status score) as a proxy for ecological integrity

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.2.2 Species condition (subgoal of biodiversity)

This goal aims to assess the average condition of the marine species within each region based on IUCN status. The target for the species subgoal is to have all species at a risk status of Least Concern.

5.2.2.1 Current status

Species status was calculated as the area and status-weighted average of assessed species within each region. Marine species distribution and threat category data mostly came from IUCN Red List of Threatened Species, and we limited data to all species having IUCN habitat system of "marine" http://www.iucnredlist.org (http://www.iucnredlist.org). Seabird distributions data came from Birdlife International http://datazone.birdlife.org (http://datazone.birdlife.org).

We scaled the lower end of the biodiversity goal to be 0 when 75% species are extinct, a level comparable to the five documented mass extinctions (Barnosky *et al.* 2011) and would constitute a catastrophic loss of biodiversity.

Threat weights, w_i, were assigned based on the IUCN threat categories status of each i species, following the weighting schemes developed by Butchart et al. (2007) (Table 5.3). For the purposes of this analysis, we included only data for extant species for which sufficient data were available to conduct an assessment. We did not include the Data Deficient classification as assessed species following previously published guidelines for a mid-point approach (Schipper *et al.* 2008; Hoffmann *et al.* 2010).

We first calculated each the region's area-weighted average species risk status, $\bar{R}_{spp}$. For each 0.5 degree grid cell within a region, c, the risk status, w, for each species, i, present is summed and multiplied by cell area A_c, to get an area- and count-weighted species risk for each cell. This value is then divided by the sum of count-weighted area $A_c \times N_c$ across all cells within the region. The result is the area-weighted mean species risk across the entire region.

$$\bar{R}_{spp} = \frac{\sum_{c=1}^{M}\left(\sum_{i=1}^{N_c} w_i\right) \times A_c}{\sum_{c=1}^{M} A_c \times N_c}, (Eq. 5.4)$$

To convert $\bar{R}_{spp}$ into a score, we set a floor at 25% (representing a catastrophic loss of biodiversity, as noted above) and then rescaled to produce a x_{spp} value between zero and one.

$$x_{spp} = max\left(\frac{\bar{R}_{SPP} - .25}{.75}, 0\right), (Eq. 5.5)$$

Table 5.3. Weights for assessment of species status based on IUCN risk categories

Risk Category	IUCN code	Weight
Extinct	EX	0.0
Critically Endangered	CR	0.2
Endangered	EN	0.4

Vulnerable	VU	0.6
Near Threatened	NT	0.8
Least Concern	LC	1.0

5.2.2.2 Trend

We calculate trend using data the IUCN provides for current and past assessments of species, which we use to estimate annual change in IUCN risk status for each species. We then summarize these species trend values for each region using the same general approach used to calculate status.

5.2.2.3 Data

Status and trend

Average species condition (http://ohi-science.org/ohi-global/layers.html#average_species_condition) (spp_status): Overall measure of species condition based on IUCN status of species within each region

Average species condition trend (http://ohi-science.org/ohi-global/layers.html#average_species_condition_trend) (spp_trend): Overall measure of species condition trends based on change in IUCN status of species within each region

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

UV radiation (http://ohi-science.org/ohi-global/layers.html#uv_radiation) (cc_uv): Pressure due to increasing frequency of UV anomolies

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Targeted harvest of cetaceans and marine turtles (http://ohi-science.org/ohi-global/layers.html#targeted_harvest_of_cetaceans_and_marine_turtles) (fp_targetharvest): Targeted harvest of cetaceans and marine turtles

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Nutrient pollution (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution) (po_nutrients): Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Genetic escapes (http://ohi-science.org/ohi-global/layers.html#genetic_escapes) (sp_genetic): Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_management_effectiveness) (fp_mora_artisanal): Quality of management of small-scale fishing for artisanal and recreational purposes

EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(fishing_preservation)) (fp_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

CITES signatories (http://ohi-science.org/ohi-global/layers.html#cites_signatories) (g_cites): Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signatories

Management of mariculture to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_mariculture__to_preserve_biodiversity) (g_mariculture): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: mariculture related questions

Management of tourism to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_tourism_to_preserve_biodiversity) (g_tourism): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: tourism related questions

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(habitat_preservation)) (hd_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.3 Coastal protection

This goal aims to assess the amount of protection provided by marine and coastal habitats 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. At global scales, such data do not exist and so we focused on EEZ-scale assessments, even though this scale does not allow one to account for the spatial configuration of habitats relative to coastal areas and human populations. Consequently, we assumed that all coastal areas have value (and equal value) and assessed the total area and condition of key habitats within each EEZ (without regard to their precise location relative to coastal areas). The habitats that provide protection to coastal areas for which we have global data include mangroves, coral reefs, seagrasses, salt marshes (Table 5.2), and coastal sea ice (shoreline pixels with >15% ice cover).

5.3.0.1 Current status

The status of this goal, x_{cp}, was calculated to be a function of the relative health of the habitats, k, within a region that provide shoreline protection, weighted by their area and protectiveness rank (Table 5.4), such that:

$$x_{cp} = \frac{\sum_{k=1}^{N} (h_k \times w_k \times A_k)}{\sum_{k=1}^{N} (w_k \times A_k)}, (Eq. 5.6)$$

where, w is the rank weight of the habitat's protective ability, A is the area within a region for each k habitat type, and h is a measure of each habitat's condition:

$$h = \frac{C_c}{C_r}$$

where, C_c is current condition and C_r is reference condition.

Table 5.4. Coastal protectiveness ranks Scores range from 1-4, with 4 being the most protective (Tallis *et al.* 2011).

Habitat	**Protectiveness rank (w)**
mangroves	4
salt marshes	4
coastal sea ice	4
coral reefs	3
seagrasses	1

The reference area for each habitat is treated as a fixed value; in cases where current area might exceed this reference value (e.g., through restoration), we cap the score at the maximum value (1.0). Although this does not give credit for restoration, data tend to be of poor quality making it difficult to determine true increases, and in general habitat restoration beyond reference values is extremely unlikely. Rank weights for the protective ability of each habitat (w_k) come from previous work (Tallis *et al.* 2011).

5.3.0.2 Trend

The trend for this goal is calculated using different methods for each habitat due to data availability (Table S8, with sea ice shoreline following the same general methods as sea ice edge).

5.3.0.3 Data

Status and trend

Habitat extent of coral (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_coral) (hab_coral_extent): Area of coral habitat

Habitat condition of coral (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_coral) (hab_coral_health): Current condition of coral habitat relative to historical condition

Habitat condition trend of coral (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_coral) (hab_coral_trend): Estimated trend in coral condition

Habitat extent of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_mangrove) (hab_mangrove_extent): Area of mangrove habitat

Habitat condition of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_mangrove) (hab_mangrove_health): Current condition of mangrove habitat relative to historical condition

Habitat condition trend of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_mangrove) (hab_mangrove_trend): Estimated trend in mangrove condition

Habitat extent of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_saltmarsh) (hab_saltmarsh_extent): Area of saltmarsh habitat

Habitat condition of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_saltmarsh) (hab_saltmarsh_health): Current condition of saltmarsh habitat relative to historical condition

Habitat condition trend of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_saltmarsh) (hab_saltmarsh_trend): Estimated trend in saltmarsh condition

Habitat extent of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_seagrass) (hab_seagrass_extent): Area of seagrass habitat

Habitat condition of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_seagrass) (hab_seagrass_health): Current condition of seagrass habitat relative to historical condition

Habitat condition trend of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_seagrass) (hab_seagrass_trend): Estimated trend in seagrass condition

Habitat extent of seaice (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_seaice) (hab_seaice_extent): Area of seaice (edge and shoreline) habitat

Habitat condition of seaice (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_seaice) (hab_seaice_health): Current condition of seaice habitat relative to historical condition

Habitat condition trend of seaice (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_seaice) (hab_seaice_trend): Estimated trend in seaice condition

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

UV radiation (http://ohi-science.org/ohi-global/layers.html#uv_radiation) (cc_uv): Pressure due to increasing frequency of UV anomolies

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(habitat_preservation)) (hd_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.4 Carbon storage

The present-day pelagic ocean sink for anthropogenic carbon dioxide, estimated at approximately 2000 TgC yr^{-1}, accounts for about a quarter of total anthropogenic CO_2 emissions to the atmosphere and helps mitigate a key driver of global climate change (Le Quéré *et al.* 2009; Sabine & Tanhua 2010). The physical-chemical mechanisms driving the ocean sink are well understood but are not directly amenable to human management. Highly productive coastal wetland ecosystems (e.g., mangroves, salt marshes, seagrass beds) have substantially larger areal carbon burial rates than terrestrial forests, and "Blue Carbon" has been suggested as an alternate, more manageable carbon sequestration approach. The rapid destruction of these coastal habitats may release large amounts of buried carbon back into the ocean-atmosphere system. Donato and colleagues (2011), for example, estimate that mangrove deforestation generates emissions of 20-120 TgC yr^{-1}. Our focus here, therefore, is on coastal habitats because they are threatened, have large amounts of stored carbon that would rapidly be released with further habitat destruction, have the highest per-area sequestration rates of any habitat on the planet, and are amenable to management, conservation, and restoration efforts. We refer to this goal as carbon storage but intend its meaning to include sequestration.

We focused on three coastal habitats known to provide meaningful amounts of carbon storage (Table 5.2): mangroves, seagrasses, and salt marshes (Duarte 2000). For mangroves, we used coastal mangroves that are on land or in river deltas.

5.4.0.1 Current status

We measured the status of carbon storage, x_{cs}, as a function of the carbon storing habitats' current condition, C_c, relative to their reference condition, C_r. The habitat condition values were averaged, weighted by the area of each habitat, A_k, and a coefficient, w_k, to account for the relative contribution of each habitat type, k, to total carbon storage (Laffoley & Grimsditch 2009) (Table 5.5):

$$x_{cs} = \frac{\sum_{k=1}^{N} (h_k \times w_k \times A_k)}{\sum_{k=1}^{N} (w_k \times A_k)}, (Eq. 5.7)$$

where:

$$h = \frac{C_c}{C_r}$$

We employed several different methods for calculating habitat condition scores depending on the habitat of interest and available data (Table 5.2).

Table 5.5. Carbon sequestration data Weighting factors based on carbon sequestration rates for habitats used in the carbon storage goal (Laffoley & Grimsditch 2009).

Habitat carbon storage	Sequestration (weight)
Mangrove	139
Saltmarsh	210
Seagrass	83

We scaled each region's score to habitat area for two reasons. First, it avoids penalizing a country that naturally lacks one of the habitats (e.g., Canada is too cold to have mangroves). Second, it ensures that habitats influence the goal score proportionately to their area of extent. This rewards the protection of large extents of habitat but does not assign a higher weight to higher habitat diversity. As such, our measure underestimates the actual amount of carbon storage being done by these coastal habitats (because we cannot account for habitats we do not know exist).

Reference area for each habitat is treated as a fixed value; in cases where current area might exceed this reference value (e.g., through restoration), we cap the score at the maximum value (1.0). Although this does not give credit for restoration efforts improving things, data tend to be of poor quality making it difficult to determine true increases, and in general habitat restoration beyond reference values is extremely unlikely.

5.4.1 Trend

The trend for this goal is calculated using different methods for each habitat due to data availability (Table 5.2).

5.4.1.1 Data

Status and trend

Habitat extent of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_mangrove) (hab_mangrove_extent): Area of mangrove habitat

Habitat condition of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_mangrove) (hab_mangrove_health): Current condition of mangrove habitat relative to historical condition

Habitat condition trend of mangrove (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_mangrove) (hab_mangrove_trend): Estimated trend in mangrove condition

Habitat extent of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_saltmarsh) (hab_saltmarsh_extent): Area of saltmarsh habitat

Habitat condition of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_saltmarsh) (hab_saltmarsh_health): Current condition of saltmarsh habitat relative to historical condition

Habitat condition trend of saltmarsh (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_saltmarsh) (hab_saltmarsh_trend): Estimated trend in saltmarsh condition

Habitat extent of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_seagrass) (hab_seagrass_extent): Area of seagrass habitat

Habitat condition of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_of_seagrass) (hab_seagrass_health): Current condition of seagrass habitat relative to historical condition

Habitat condition trend of seagrass (http://ohi-science.org/ohi-global/layers.html#habitat_condition_trend_of_seagrass) (hab_seagrass_trend): Estimated trend in seagrass condition

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(habitat_preservation)) (hd_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.5 Clean waters

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, algal blooms, disease pathogens (e.g., fecal coliform, viruses, and parasites from sewage outflow), floating trash, and mass kills of organisms due to pollution. People are sensitive to these phenomena occurring in areas 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.

We include four measures of pollution in the clean waters goal: eutrophication (nutrients), chemicals, pathogens and marine debris. This decision was meant to represent a comprehensive list of the contamination categories that are commonly considered in assessments of coastal clean waters (Borja *et al.* 2008) and for which we could obtain datasets (Table 5.6). The status of these components is the inverse of their intensity (i.e., high input results in low status score).

Table 5.6. Clean waters goal components

Component	Data	Trend
Eutrophication (nutrient)	FAO fertilizer data (Halpern *et al.* 2008; United Nations 2016c)	Standard method (section 4.3.1)
Chemical	Land-based organic pollution (FAO pesticide data), Land-based inorganic pollution (based on run-off from impermeable surfaces), ocean-based pollution based on commercial shipping and port traffic (Halpern *et al.* 2008; United Nations 2016c)	Trend based only on changes in organic pollution, other variables remained the same
Pathogens	Proportion of population without access to improved sanitation facilities (WHO-UNICEF 2017)	Standard method
Marine debris	Plastic pollution (Eriksen *et al.* 2014)	Data on improperly disposed of plastics (Jambeck *et al.* 2015)

We used the modeled input of land-based nitrogen input from Halpern et al. (2008) as a proxy for nutrient input. The modeled proxy approach does not allow the distinction between toxic and non-toxic bloom events that can arise from excess nutrient input (often both referred to in the literature as harmful algal blooms, or HABs) or at what nutrient concentration an ecosystem is pushed into a HAB condition (i.e., the threshold value). Local studies may be able to obtain information on such non-linear responses and include it as part of this status measure.

For the chemical pollution component (Halpern *et al.* 2008), we used a combination of modeled input of fertilizer input as a proxy for land-based organic pollution, and impermeable surfaces as a proxy for land-based organic pollution, and shipping and port traffic for ocean based pollution. 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. We also did not have global data for oil spills and so could not include oil pollution, but in future assessments where such data exist it would be included in chemical pollution as well.

Human-derived pathogens are found in coastal waters primarily from sewage discharge or direct human defecation. Since we did not have access to a global database of in situ measurements of pathogen levels, we used a proxy measure for the status of pathogen pollution, namely the number of people in coastal areas without access to improved sanitation facilities (WHO-UNICEF 2017). The underlying assumption is that locations with a low number of people with access to improved facilities will likely have higher levels of coastal water contamination from human pathogens. To estimate this pathogen intensity, we multiplied the human population within 25 miles of the coast by the percentage of population without access to improved sanitation. This allows countries with low coastal population densities and low access to improved sanitation to score better than high population countries with better access if the absolute number of people without access is lower in the small country.

The status of trash pollution was estimated using globally-available plastic pollution data (Eriksen *et al.* 2014).

5.5.0.1 Current status

The status of this goal, x_{cw} , was calculated as the geometric mean of the four components, such that:

$$x_{cw} = \sqrt[4]{a * u * l * d}, (Eq. 5.8)$$

where a = 1 - the number of people without access to sanitation, rescaled to the global maximum; u = 1 – (nutrient input), rescaled at the raster level by the 99.99th quantile value; l = 1 – (chemical input), rescaled at the raster level by the 99.99th quantile value; and d = 1 – (marine debris), rescaled at the raster level by the 99.99th quantile value.

We used a geometric mean, as is commonly done for water quality indices (Liou *et al.* 2004), because a very bad score for any one subcomponent would pollute the waters sufficiently to make people feel the waters were 'too dirty' to enjoy for recreational or aesthetic purposes (e.g., a large oil spill trumps any other measure of pollution). However, in cases where a subcomponent was zero, we added a value of 0.01 (on a scale of 0 to 1) to prevent the overall score from going to zero. Given that there is uncertainty around our pollution estimates, a zero score resulting from one subcomponent seemed too extreme.

Although clean waters are relevant and important anywhere in the ocean, coastal waters drive this goal both because the problems of pollution are concentrated there and because people predominantly access and care about clean waters in coastal areas. The nearshore area is what people can see and where beach-going, shoreline fishing, and other activities occur. Furthermore, the data for high seas areas is limited and there is little meaningful regulation or governance over the input of pollution into these areas. We therefore calculate this goal only for the first 3 nm of ocean for each country's EEZ. We chose 3 nm for several reasons, but found the status results to be relatively insensitive to different distances.

A number of potential components of clean water were not included due to lack of global datasets, including toxic algal blooms, oil spills, turbidity (sediment input), and floating trash. In future applications of the Index where such data are available, they would be included in their appropriate component of clean waters (nutrients, chemicals, and trash, respectively).

5.5.0.2 Trend

Trends in eutrophication, pathogens, and chemical pollution are estimated as described in section 4.3.1. Because only one of the inputs (organic pollution) of the chemical pollution layer includes data over time, the trend only reflects this input. Marine debris trends are estimated using a secondary dataset describing the amount of improperly disposed of plastics within each country (Jambeck *et al.* 2015).

5.5.0.3 Data

Status and trend

Chemical pollution trend (http://ohi-science.org/ohi-global/layers.html#chemical_pollution_trend) (cw_chemical_trend): Trends in chemical pollution, based on commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution) within EEZ

Nutrient pollution trend (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution_trend) (cw_nutrient_trend): Trends in nutrient pollution, using fertilizer consumption as a proxy for nutrient pollution

Pathogen pollution trend (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution_trend) (cw_pathogen_trend): Trends in percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Plastic trash trends (http://ohi-science.org/ohi-global/layers.html#plastic_trash_trends) (cw_trash_trend): Trends in trash estimated using improperly disposed of plastics

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Pathogen pollution (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution) (po_pathogens): Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Pressure

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Pathogen pollution (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution) (po_pathogens): Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.6 Food Provision

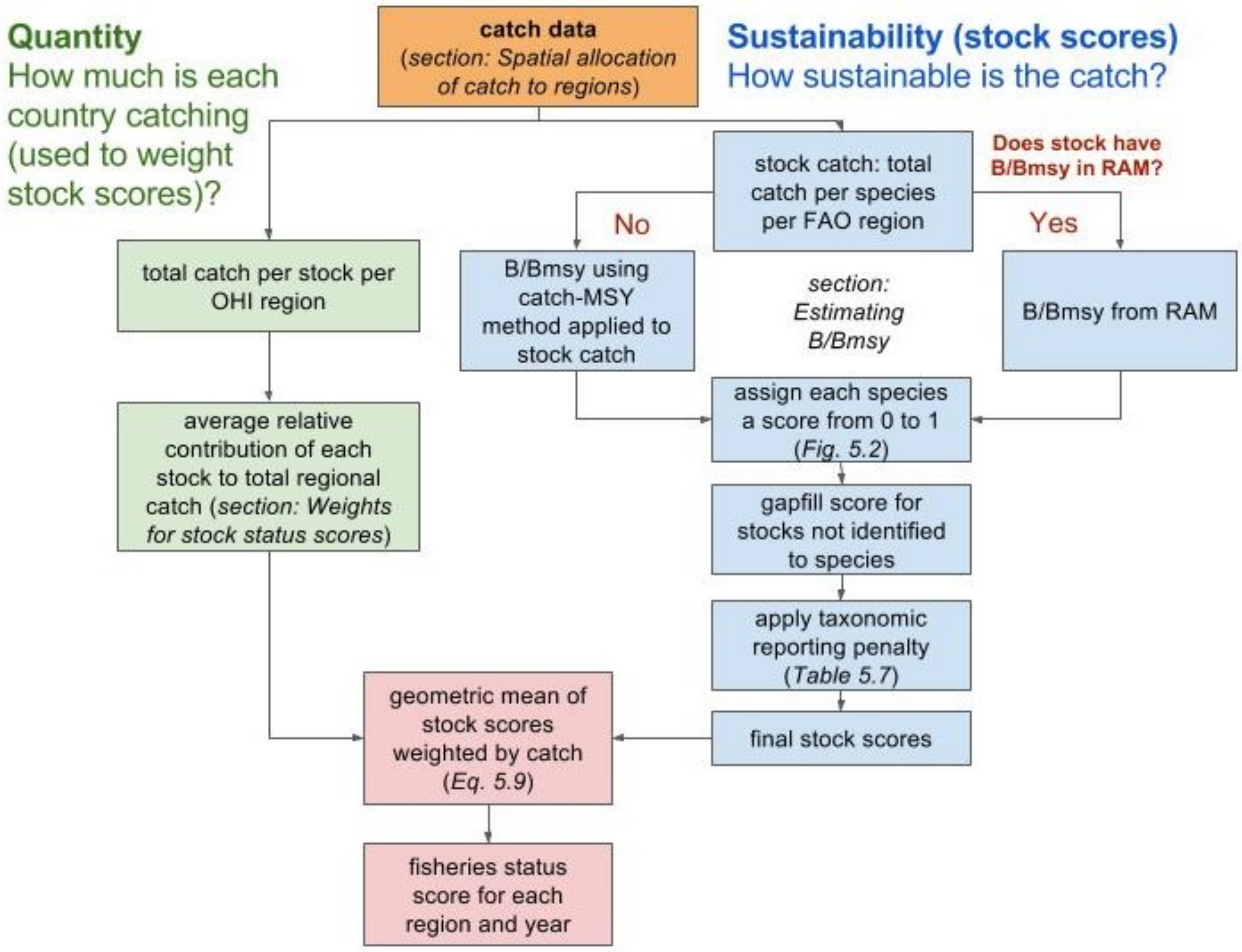
One of the most fundamental services the ocean provides people is the provision of seafood. From meeting the basic nutritional needs of over half of the world's population to being sold in high-end sushi restaurants, seafood is an important benefit of healthy oceans. This goal measures the amount of seafood sustainably harvested within an EEZ or region through any means for use primarily in human consumption and thus includes wild-caught commercial fisheries, mariculture, artisanal-scale and recreational fisheries. Importantly, seafood harvest using unsustainable fishing practices or catch levels is penalized, as well as underexploitation of a sustainable resource as the goal aims to maximize the amount of sustainably produced seafood from wild or cultured stocks. Because we do not track where the fish go after being caught or produced, this goal does not aim to measure food security for the population of a given country, but instead measures the food provided from its waters.

The status of the food provision goal is calculated as the mean of the fisheries and mariculture subgoals, weighted by their relative contribution in tonnes to food production for each region.

5.6.1 Fisheries (subgoal of food provision)

This model aims to assess the amount of wild-caught seafood that can be sustainably harvested with penalties assigned for both over- and under-harvesting. As such, one must establish a reference point at which harvest is both maximal and sustainable. We assess food provision from wild caught fisheries by estimating population biomass relative to the biomass that can deliver maximum sustainable yield (B/B_{MSY}) for each stock. When available, we obtained B/B_{MSY} values from the RAM Legacy Stock Assessment Database (Ricard *et al.* 2012), which contains stock assessment information for a portion of global fish stocks. When RAM data were not available, we used data-limited approaches that have been developed to estimate B/B_{MSY} values using globally available catch data (Costello *et al.* 2012, 2016; Martell & Froese 2013; Thorson *et al.* 2013; Rosenberg *et al.* 2014). To calculate the status for each region and year, B/B_{MSY} values were converted to a stock status score between 0-1 that penalizes both over- and under-harvesting. To obtain the overall status for each region, the stock status scores for all the stocks within a region were averaged using a geometric mean weighted by the average catch (tonnes) of each stock.

Figure 5.1: Overview of fisheries status calculations.



5.6.1.1 Current status

Spatial allocation of catch to regions

The data we use to calculate B/B_{MSY} and the weights used in the geometric mean are from Watson (2018) global marine fisheries catch data (Watson & Tidd 2018). Watson (2018) uses a spatial allocation method to distribute FAO catch data (reported at the country scale) to a global grid of one half-degree cell resolution based on the spatial distribution of fished taxa and the allocation of catch to fleets based on fishing access agreements (Zeller *et al.* 2016).

We aggregate the Watson (2018) catch data in two ways. To get the data needed to weight the stock status scores, we sum the total catch for each taxa within each region's EEZ to get the total catch in tonnes for each year. To get the data needed to calculate B/B_{MSY} values, we sum the total catch for each taxa within each major fishing region (FAO Fisheries and Aquaculture Department 2015) for each year.

To combine the B/B_{MSY} values from the RAM database with the Watson (2018) global fish catch data, we used the spatial boundaries that Christopher Free created for the RAM stocks up to 2017 and assigned FAO and OHI regions to each stock (Free 2017). Newly added stocks to the RAM database in 2018 had no spatially explicit information, so were manually assigned regions based on best available information on stock distribution.

Estimating B/B_{MSY}

When we were unable to obtain B/B_{MSY} values from the RAM database for a stock, we calculated them using a data-poor, or catch only model, developed by Martell & Froese (2013), and hereafter referred to as the "catch-MSY" method. The latter was chosen, among other data-limited methods because it was as good, or better, at predicting RAM B/B_{MSY} values than other methods based on our initial testing. We compared B/B_{MSY} scores from three catch models (catch-MSY, SSCOM, and COMSIR) as well as a variety of ensemble methods (Anderson *et al.* 2017). The catch_MSY model performed as well or better than the other models at predicting RAM B/B_{MSY} values. Furthermore, this method performed well (although not as well as the Random Forest ensemble approach, based on a rank correlation analysis) in analyses using simulated stocks with a broad range of life history traits and different known sources of uncertainty (Anderson *et al.* 2017).

We defined a stock as species occurring within a major fishing area, and consequently, we ran the catch-MSY model using yearly catch data aggregated to FAO region from 1950 to the most current year. We chose this definition because many fish populations straddle the boundaries of EEZs. Any aggregation method will be biased in some way, but populations with the largest catches are most often straddling stocks, so a bias in assessments due to erroneous aggregation of catch could occur more often with cosmopolitan species that include small, sedentary (i.e., patchily distributed) populations that are less likely to play a dominant role in a country's fisheries. The catch-MSY model was applied only to stocks identified to the species level.

The catch-MSY method is based on the same assumptions used in many stock assessment models (Schaefer 1954), namely that the change in a population's biomass depends on its biomass in the previous year and two population-specific parameters: the carrying capacity (K) and rate of population increase (r). The method estimates the status of a given population using landings time-series as proxies for biomass removals from the population, and using empirically derived relationships of relative peak to current catch values to estimate depletion at the end of the time series (Martell & Froese 2013). Then, a sampling procedure is used to estimate the distribution of values of r and K that are compatible with the estimated current depletion levels, and are constrained within the range that maintains viable population abundance and at the same time does not exceed the population's carrying capacity. In the original formulation of Martell & Froese (2013) the geometric mean r and K were used to derive an estimate of MSY. Rosenberg et al. (2014) modified this method by producing a biomass time series for each of the viable $r - K$ pairs using the surplus production model. The arithmetic mean biomass time series was selected and the current year stock abundance (B) relative to the abundance that achieves MSY (B_{MSY}) produced a measure, B/B_{MSY}.

A potential issue of the catch-MSY method (when using the default "constrained" prior) is that declining catch is assumed to indicate declining population biomass (resulting in lower B/B_{MSY} values) rather than reduced effort or improved management. When declining catch is known to be due to reduced effort and/or improved management this results in artificially low B/B_{MSY} values; however, the catch-MSY model can be modified by using a "uniform" prior distribution for the final biomass. However, this adjustment should be considered carefully because the model will assume that all stocks with declining catch are rebuilding (resulting in higher B/B_{MSY} values), which is unrealistic. Previously, for the 2015 assessment, we attempted to use the constrained vs. uniform prior for each stock based on the catch weighted fishery management scores of the regions catching the stock. However, recent analyses suggest this method did not improve the ability of the catch-MSY derived B/B_{MSY} values to predict RAM values, suggesting we were adding additional complication that did not improve our model. Consequently, all analyses are done using the "constrained" prior.

Weights for stock status scores

To get the data needed to weight the stock status scores, we sum the total catch for each taxa within each region's EEZ to get the total catch in tonnes for each year. We then average each taxa's catch within each region across all years from 1980 to the most current year's data. Consequently, for a taxa within a region, the average catch value is the same across all years (only the B/B_{MSY} value will vary across years.). This provides an estimate of the mean potential contribution of each species to total food provision, independent of yearly stochastic fluctuations of the population and possible recent declines.

Goal model calculations

The status of wild caught fisheries, x_{fis}, for each reporting region in each year was calculated as the geometric mean of the stock status scores, SS (derived from B/B_{MSY} score for each stock, described below) and weighted by the stock's relative contribution to overall catch, C, such that:

$$x_{fis} = \prod_{i=1}^{n} SS_i^{(\frac{C_i}{\sum C_i})}, (Eq. 5.9)$$

where i is an individual taxon and n is the total number of taxa in the reported catch for each region throughout the time-series, and C is the average catch, since the first non null record, for each taxon within each region.

We used a geometric weighted mean to account for the portfolio effect of exploiting a diverse suite of resources, such that small stocks that are doing poorly will have a stronger influence on the overall score than they would using an arithmetic weighted mean, even though their C contributes relatively little to the overall tonnage of harvested seafood within a given region. The behavior of the geometric mean is such that improving a well-performing stock is not rewarded as much as improving one that is doing poorly. We believe this behavior is desirable because the recovery of stocks in poor condition requires more effort and can have more important effects on the system than making a species that is already abundant even more abundant. In this way, the score is not solely driven by absolute tonnes of fish produced and accounts for preserving the health of a diversity of species.

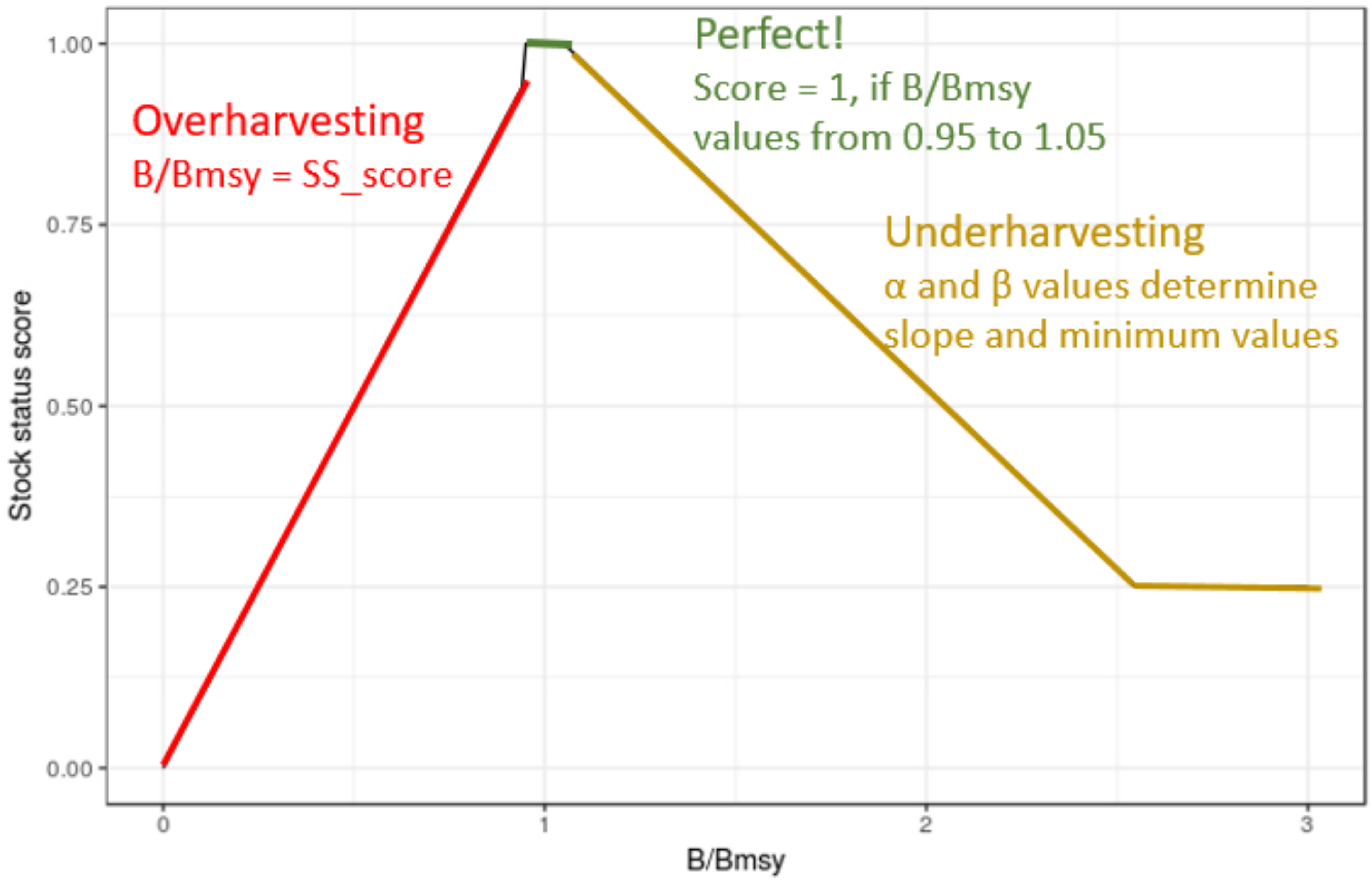
B/B_{MSY} values were used to derive stock status scores, SS, such that the best score is achieved for stocks at $B/B_{MSY} = 1\%$, with a 5% error buffer, and it decreases as the distance of B from B_{MSY} increases, due to under- or over-exploitation (Figure 5.2). For each species reported, within each major fishing area, the stock status score was calculated as:

$$SS=\begin{cases} B/B_{MSY} & if \;\; B/B_{MSY} < 0.95 \\ 1 & if \;\; 0.95 \leq B/B_{MSY} \leq 1.05 \\ max\{1-\alpha(B/B_{MSY}-1.05), \;\; \beta\} & if \;\; B/B_{MSY} > 1.05 \end{cases}$$

where, for $B/B_{MSY} < 1$ (with a 5% buffer), status declines with direct proportionality to the decline of β with respect to B_{MSY}, while for $B/B_{MSY} > 1$ (with a 5% buffer), status declines at rate α, where $\alpha = 0.5$, so that as the distance of β from B_{MSY} increases, status is penalized by half of that distance. For $B/B_{MSY} > 1.05$, β is the minimum score a stock can get, and was set at $\beta = 0.25$. The α value ensures that the penalty for under-harvested stocks is half of that for over-harvested stocks ($\alpha = 1.0$ would assign equal penalty). The β value ensures stocks with $B/B_{MSY} > 1.4$ due to, for example, an exceptionally productive year, are not unduly penalized, and also recognizes that it is much easier to improve the goal score when stocks are under-harvested (i.e., increase fishing pressure) than it is when populations are over-harvested and need to be rebuilt. Both parameters α and β were chosen arbitrarily because there is no established convention for this particular approach. Thus, consistent with previous work (Halpern *et al.* 2012), countries are rewarded for having wild stocks at the biomass that can sustainably deliver the maximum sustainable yield, +/-5% to allow for measurement error, and are penalized for both over- or under-harvesting.

For the 2016 assessment, we did not apply underharvest penalties to the following stocks: Katsuwonus pelamis (FAO region 71), Clupea harengus (FAO region 27), Trachurus capensis (FAO region 47), Sardinella aurita (FAO region 34), Scomberomorus cavalla (FAO region 31). These stocks are fished in multiple regions and the current model formulation ends up penalizing the regions that have the highest proportion of catch of these stocks, which is opposite of what we would like to do. This suggests that our approach to penalizing underharvested stocks could be improved at the model level.

Figure 5.2: Conversion of B/B_{MSY} to stock status, SS score.



We needed to gapfill missing status, SS, scores for a large proportion of the catch. Gapfilling was necessary because we could only estimate B/B_{MSY} values for taxa identified to the species level. Furthermore, we were unable to estimate B/B_{MSY} values for some species due to model non-convergence or too few years of catch data. Missing status scores were gapfilled using the mean status scores of the stocks sharing a region and year, the mean value was then adjusted using a taxonomic reporting penalty (Table 5.7). For catch not reported to the species level, a penalty was applied for increasingly coarser taxonomic reporting, as this is considered a sign of minimal monitoring and management. We based the penalty on the ISSCAAP convention for taxon codes (http://www.fao.org/fishery/collection/asfis/en (http://www.fao.org/fishery/collection/asfis/en)), which defines 6 levels of taxonomic aggregation, from 6 (species) to 1 (order or higher). When $g < 6$, a penalized gapfilled value for status was estimated for the taxa in each region:

Table 5.7: Penalty applied to gapfilled stock status scores The penalty is multiplied by the gapfilled stock status score to obtain the final stock status score.

ISSCAAP taxon code	Description	Penalty (gapfilled score multiplied by value)
1	e.g., Marine fishes not identified, Miscellaneous marine molluscs	0.1
2	Class, Subclass, Subphylum (e.g., Cephalopoda, Holocephali, Crustacea)	0.25
3	Order (e.g., Chimaeriformes, Octopoda)	0.5
4	Family (e.g., Lamnidae, Squillidae)	0.8
5	Genus (e.g., Strongylocentrotus, Scyllarides)	0.9
6	Species	1 (no penalty)

Model limitations

This model is based on single-species assessments of stock status and thus cannot predict the effect of multi-species interactions. This model adopts $B = B_{MSY}$ as a single-species reference point, which by various assessment frameworks is considered very conservative (e.g., Froese *et al.* (2011)), and the fact that the single-species values are aggregated using a geometric mean ensures that some multi-species effects may influence the scores. Nonetheless, a better understanding of the emerging effects of fishing various species at their reference levels would be desirable and will hopefully be possible in the future.

Despite the fact that invertebrates represent a large proportion of global caught biomass, and represent the dominant stocks in many regions, stock assessment approaches for these taxa are poorly developed. The catch-MSY approach was applied to invertebrates even though the model developers only tested it on fish (Martell & Froese 2013). Part of the challenge in broadly testing this approach on organisms other than fish is the lack of a large enough collection of invertebrate assessments to use for validation testing.

This approach captures whether stocks have been historically well managed, but it is worth noting that it does not directly measure current food production.

5.6.1.2 Trend

Trend was calculated as described in section 4.3.1.

5.6.1.3 Data

Status and trend

B/Bmsy estimates (http://ohi-science.org/ohi-global/layers.html#bbmsy_estimates) (fis_b_bmsy): The ratio of fish population abundance compared to the abundance required to deliver maximum sustainable yield (RAM and catch-MSY data)

Fishery catch data (http://ohi-science.org/ohi-global/layers.html#fishery_catch_data) (fis_meancatch): Mean commercial catch for each OHI region (averaged across years)

Pressure

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Nutrient pollution (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution) (po_nutrients): Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Genetic escapes (http://ohi-science.org/ohi-global/layers.html#genetic_escapes) (sp_genetic): Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_management_effectiveness) (fp_mora_artisanal): Quality of management of small-scale fishing for artisanal and recreational purposes

EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(fishing_preservation)) (fp_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(habitat_preservation)) (hd_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Measure of ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_ecological_integrity) (species_diversity_eez): Marine species condition (species subgoal status score) as a proxy for ecological integrity

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.6.2 Mariculture (subgoal of food provision)

The mariculture subgoal attempts to measure each region's food production from mariculture relative to its capacity. A basic problem facing assessments of mariculture is the lack of an ecologically- and socially-based reference point for the potential yield of every suitable mariculture species for every type of geographic habitat and location. Determining such reference points for every country at the global scale is a daunting challenge, not only because so much information is lacking, but also because species, genotypes and habitats are likely to change. Consequently, the reference point is based on a comparison of country performance of the harvested tonnes per coastal inhabitant.

5.6.2.1 Current status

The status of the mariculture subgoal, x_{mar}, was defined as production of strictly marine taxa from both the marine and brackish water FAO categories, excluding species that were not used as a source of food for human consumption. Seaweeds are included, but the tonnes of harvest is multiplied by 0.2 to adjust for protein content relative to fish and shellfish mariculture. The data reported by FAO does not always clearly describe whether harvest is derived through mariculture or from land-based facilities. Wherever possible, we excluded species that could not have been harvested from coastal waters, such as freshwater cyclids. Mariculture status was therefore assessed as the current sustainably-harvested yield, Y_c, within each country, such that:

$$x_{mar} = \frac{Y_c}{Y_{c,ref}}, (Eq. 5.10)$$

where, $Y_{c,ref}$ is the Y_c value that corresponds to the 95th quantile across all regions and years (including and prior to the year of the assessment year data), and Y_c is:

$$Y_c = \frac{\sum_{k=1}^{N} Y_k S_{k,r}}{P_r}, (Eq. 5.11)$$

where, Y_k is the 4-year moving window average of tonnes of production (United Nations 2016b) for each k mariculture species that is currently or at one time cultured within a country, $S_{k,r}$ is the sustainability score for each k mariculture species and region, and P_r is the population within 25 miles of the region's coast.

Sustainable harvest data is adjusted for coastal population within a country given the assumption that production depends on the presence of coastal communities that can provide the labor force, infrastructures, and economic demand to support the development and economic viability of mariculture facilities. Thus, two regions with an equal number of coastal inhabitants harvesting an equal tonnage of cultured seafood will score the same, as productivity is commensurate to each region's socio-economic potential to develop mariculture. Stated another way, mariculture development is assumed to scale proportionally with coastal population, which is a proxy for potential logistic limitations to farm development, e.g., presence of infrastructures, coastal access, and locally available workforce.

The reference point was the Y_c value of the region scoring in 95th percentile across all years of data, with all regions scoring above that value given a status score of 1.0.

The sustainability score, $S_{k,r}$, for each species in each region is based on the Mariculture Sustainability Index (MSI, Summerson & Peterson (1990)). We used the three sub-indices that directly measured long-term renewability of a given mariculture practice: the wastewater treatment index, the origin of feed index (i.e., fishmeal or other) and the origin of seed (i.e., hatchery or wild caught). These scores are country and species-specific, and we require each species' yield, Y_k, to have a corresponding sustainability score, $S_{k,r}$. However, if a country farms a species that was not assessed by the MSI for that country, but it was assessed in other countries, a global average score is used for that species and country. If a country farms a species that was not assessed at all by the MSI but a species within the same genus was assessed, a global average for the genus was used. Finally, if these scores were not available for the categories above, we used the global average for broad taxonomic grouping (e.g., crustaceans, algae, bivalves, etc.). We are aware that there is some bias associated with using scores derived as averages across countries because they were originally assigned to specific species-country pairs, nevertheless this is preferable to applying a sustainability score solely based on a subset of the species harvested.

5.6.2.2 Trend

Trend was calculated as described in section 4.3.1.

5.6.2.3 Data

Status and trend

Inland coastal population (http://ohi-science.org/ohi-global/layers.html#inland_coastal_population) (mar_coastalpopn_inland25mi): Total coastal population within 25 miles of coast

Mariculture harvest (http://ohi-science.org/ohi-global/layers.html#mariculture_harvest) (mar_harvest_tonnes): Tonnes of mariculture harvest

Mariculture sustainability score (http://ohi-science.org/ohi-global/layers.html#mariculture_sustainability_score) (mar_sustainability_score): Mariculture sustainability based on the Mariculture Sustainability Index (MSI)

Pressure

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of mariculture to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_mariculture__to_preserve_biodiversity) (g_mariculture): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: mariculture related questions

Mariculture Sustainability Index (http://ohi-science.org/ohi-global/layers.html#mariculture_sustainability_index) (g_msi_gov): Mariculture practice assessment criteria from the Mariculture Sustainability Index (MSI)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.7 Livelihoods and economies

Due to discontinued and non-updated source datasets, we have not updated the status of this goal since 2013 (changes across scenario years after 2013 are due to changes in pressures/resilience).

The jobs and revenue 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.

This goal is composed of two equally important sub-goals, livelihoods and economies, which are assessed across as many marine-related sectors as possible (Table 5.8). Livelihoods 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. Economies is composed of a single component, revenue. We track the two halves of this goal 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 in some cases (e.g., high revenue sectors do not necessarily provide large employment opportunities). The status of the livelihoods and economies goal is the average of the livelihoods and economies subgoals.

The total value of economic industries cannot be captured fully by measuring only the jobs and revenue generated directly by those industries, since activity in the direct industry stimulates additional jobs and revenue in related industries. For example, the fishing industry provides direct jobs to fishers, indirect jobs to fishing gear manufacturing companies, and induced jobs to the restaurants and movie theaters where those manufacturing employees spend their income. In the case of tourism, data describing total jobs and revenue (direct plus indirect and induced) were available from the primary data source, and so we used that information as the best estimate of total employment and total revenue for that sector. For all other sectors we used sector- and development status-specific multipliers derived from the literature to estimate total job or revenue impacts. We did not apply multiplier values to wages since the cascading effects of earned income are more contentious. We assumed that sector-specific job and revenue multipliers are static and globally consistent, but distinct for developed versus developing countries (when such information was available), because we do not have data to resolve temporal or regional differences (Table 5.9). Countries were classified as developed or developing using the Human Development Index (HDI, UNDP (2010)), with all countries identified as "very high human development" classified as developed and all others as developing. We classified regions not assessed by the HDI by compiling information used to calculate the HDI score (schooling, life expectancy and per capita Gross National Income statistics).

For a job or wage sector to be included in our assessment it needed to report at least two time points and have data for all or most coastal regions (reported separately, not as a single global number). However, a sector did not need to have data for all three measures – jobs, wages, and revenue – as this would have eliminated almost every sector. Consequently, the sectors that comprise each of the three measures differ (Table 5.8) and there is variation across regions in which sectors and measures comprise the status score (because of gaps in datasets and the fact that not all sectors exist in all countries). If a region only had one data layer (a single sector for only one measure), a status score was not calculated for that region and instead, a regional average was applied. We used a weighted average of the region's UN geopolitical region; revenue values were weighted by each region's GDP, jobs were weighted by each region's workforce size, and wages were unweighted.

A number of sectors were not included primarily because sufficient data do not exist. In the future, particularly in finer scale applications, it would be desirable to include these sectors, including (but not limited to) ecotourism (beyond just cetacean watching), sailing/kayaking/boating, surfing/kiteboarding, etc., offshore wind and wave energy, navigation assistance, safety and security, coastal development, scientific research, and restoration and conservation.

Table 5.8. Livelihoods and economies sectors. Sectors for which data were available for each component of the livelihoods and economies goal.

Sector	Jobs data	Wages data	Revenue data
Tourism	X	X	X
Commercial fishing	X	X	X
Marine mammal watching	X		
Aquarium fishing			X
Wave & renewable energy	X		X
Mariculture	X		X
Transportation & shipping		X	
Ports & harbors		X	
Ship & boatbuilding		X	

Table 5.9. Sector multipliers. Sector-specific multipliers used to calculate total jobs and total revenue created by sector-based employment in developing and developed nations. N/A (not applicable) indicates that total employment or total revenue (direct plus indirect and induced) data were provided by primary data source, eliminating the need for a multiplier value. ND indicates no data available for that sector.

	Developed Countries		Developing Countries	
Sector	Jobs	Revenue	Jobs	Revenue
Tourism	N/A	N/A	N/A	N/A
Commercial fishing	1.582	1.568	1.582	1.568
Marine mammal watching	1.915	1.0	1.915	1.0
Aquarium fishing	ND	1.568	ND	1.568
Wave & tidal energy	1.88	1.652	1.88	1.652
Mariculture	2.7	2.377	1.973	1.59

This goal aims to maintain coastal livelihoods and economies (i.e., avoid the loss of, coastal and ocean-dependent jobs and revenues), while also maximizing livelihood quality (relative wages). It does not attempt to capture any aspects of job identity (i.e., the reputation, desirability or other social or cultural perspectives associated with different jobs), although one can examine the component parts that make up this goal to evaluate individual sectors and infer implications for job identity. We make the assumption that all marine-related jobs are equivalent, such that, for example, a fisherman could transition to a job in mariculture or ship-building without affecting the score of this goal. While job identity has social and cultural value, there are not adequate data to track individual workers and assess their job satisfaction on a global scale. We also do not include any measure of petroleum extraction, as we do not consider these practices to be related to the biophysical state of the system and, because they rely on a non-renewable resource, they are inherently unsustainable. Furthermore, because of data constraints, this goal does not provide more credit for sectors or economic activities that are more ecologically sustainable. Future, finer scale applications of the Index may incorporate these key considerations.

Gaps were filled in the adjustment datasets (national GDP and national employment) by first determining the average metric value (e.g., average employment rate) in UN geopolitical regions (United Nations (2013d)) for each year based on all countries in that region for which there were data. Using these regional average time series, we fit nonlinear models to the adjustment data. Using the model fit, we determined the slope between each year. To fill in missing data points in country time series, we applied the slope (percent change in the metric) between the missing year and the following year (or previous year, if necessary). We prioritized filling in backwards (e.g., if a country has data from 2006 and 2008, to fill in 2007, one would use the regional delta between 2008 and 2007), but filled forwards when there were no data for a subsequent year.

5.7.1 Economies (subgoal of livelihoods and economies)

This subgoal measures the revenue produced from marine-related industries.

5.7.1.1 Current status

The model to estimate the status of the economies sub-goal, x_{eco} , is:

$$x_{eco} = \frac{\sum_{k=1}^{N} e_{c,k}}{\sum_{k=1}^{N} e_{r,k}}, (Eq. 5.12)$$

where, e is the total adjusted revenue generated directly and indirectly from sector k, at current, c, and reference, r, time points.

Because there is no absolute global reference point for revenue (i.e., a target number would be completely arbitrary), the economies subgoal uses a moving baseline as the reference point. Reference revenue is calculated as the value in the current year (or most recent year), relative to the value in a recent moving reference period, defined as 5 years prior to the current year. This reflects an implicit goal of maintaining coastal revenue on short time scales, allowing for decadal or generational shifts in what people want and expect. We allowed for a longer or shorter gap between the current and recent years if a 5 year span was not available from the data, but the gap could not be greater than 10 years. Our preferred gap between years was as follows (in order of preference): 5, 6, 4, 7, 3, 8, 2, 9, 1, and 10 years.

Absolute values for e in the current and reference periods were lumped across all sectors before calculating reference values (even though the current and reference years will not be exactly the same for all sectors), allowing a decrease in one sector to be balanced by an increase in another sector. As such, we do not track the status of individual sectors and instead always focus on the status of all sectors together.

To control for inflation/deflation, we used a standard dollar year. To account for broader economic forces that may affect revenue independent of changes in ocean health (e.g., a global recession), we adjusted revenue based on a country's GDP (i.e., must keep pace with growth in GDP). The current and reference years used for GDP data were based on the average current year and average reference year across the sector data sources used for revenue.

5.7.1.2 Trend

Trend was calculated as the slope in the individual sector values (not summed sectors) for revenue over the most recent five years (as opposed to the status, which examines changes between two points in time, current versus five years prior to current), corrected by GDP. We calculated the average for revenue by averaging slopes across sectors weighted by the revenue in each sector.

5.7.1.3 Data

Status and trend

Economic status scores (http://ohi-science.org/ohi-global/layers.html#economic_status_scores) (eco_status): Calculated using corrected revenue data for several marine sectors (data not updated since 2013)

Economic trend scores (http://ohi-science.org/ohi-global/layers.html#economic_trend_scores) (eco_trend): Calculated using change in revenue for several marine sectors (data not updated since 2013)

Sectors in each region (http://ohi-science.org/ohi-global/layers.html#sectors_in_each_region) (le_sector_weight): Proportion of jobs within each marine sector

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Nutrient pollution (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution) (po_nutrients): Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Pathogen pollution (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution) (po_pathogens): Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Genetic escapes (http://ohi-science.org/ohi-global/layers.html#genetic_escapes) (sp_genetic): Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Global Competitiveness Index (GCI) (http://ohi-science.org/ohi-global/layers.html#global_competitiveness_index_(gci)) (li_gci): Competitiveness in achieving sustained economic prosperity

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.7.2 Livelihoods (subgoal of livelihoods and economies)

This subgoal measures the jobs produced from marine-related industries. Livelihoods 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.

5.7.2.1 Current status

The status of the livelihoods sub-goal, x_{liv} , is calculated as:

$$x_{liv} = \frac{\frac{\sum_1^k j_{c,k}}{\sum_1^k j_{r,k}} + \frac{\sum_1^k w_{m,k}}{\sum_1^k w_{r,k}}}{2}, (Eq. 5.13)$$

where j is the adjusted number of direct and indirect jobs within sector k within a region and w is the average PPP-adjusted wages per job within the sector. Jobs are summed across sectors and measured at current, c, and reference, r, time points. Adjusted wage data are averaged across sectors within each region, m, and the reference country, r, with the highest average wages across all sectors.

Because there is no absolute global reference point for jobs (i.e., a target number would be completely arbitrary), this component of the livelihoods subgoal uses a moving baseline as the reference point. Jobs, j, are calculated as a relative value: the value in the current year (or most recent year), c, relative to the value in a recent moving reference period, r, defined as 5 years prior to c. This reflects an implicit goal of maintaining coastal jobs on short time scales, allowing for decadal or generational shifts in what people want and expect. We allowed for a longer or shorter gap between the current and recent years if a 5 year span was not available from the data, but the gap could not be greater than 10 years. Our preferred gap between years was as follows (in order of preference): 5, 6, 4, 7, 3, 8, 2, 9, 1, and 10 years. For wages, w, we assumed the reference value was the highest value observed across all regions.

Absolute values for j and w in the current and reference period (jobs) or region (wages) were lumped across all sectors before calculating relative values (even though the current and reference years will not be exactly the same for all sectors), allowing a decrease in one sector to be balanced by an increase in another sector. As such, we do not track the status of individual sectors and instead always focus on the status of all sectors together. For wages, we use the most current data available for each country and each sector, but only use data from 1990 on, assuming that wages are relatively slow to change over time (apart from inflation adjustments, which we control for by using real dollars) and thus can be compared across sectors and countries without controlling for year.

Wages data were divided by the inflation conversion factor so that wage data across years would be comparable in 2010 US dollars (inflation conversion factors were downloaded from http://oregonstate.edu/cla/polisci/sahr/sahr (http://oregonstate.edu/cla/polisci/sahr/sahr)). These data were also multiplied by the purchasing power parity-adjusted per capita GDP https://data.worldbank.org/indicator/NY.GDP.PCAP.CD (https://data.worldbank.org/indicator/NY.GDP.PCAP.CD). To account for broader economic forces that may affect jobs independent of changes in ocean health (e.g., a global recession), we adjusted jobs data by dividing by percent employment for the corresponding year: (1 – percent unemployment) * total labor force (World Bank 2014b,c). For example, if unemployment increased from the reference to the current period, we would expect the number of marine-related jobs to decrease by a comparable proportion, without causing a lower score for the goal. Therefore, the objective of the goal is actually no loss of jobs and jobs must keep pace with growth in employment rates or sustain losses no greater than national increases in unemployment rates. The current and reference years used for unemployment data were based on the average current year and average reference year across the sector data sources used for number of jobs.

5.7.2.2 Trend

Trend was calculated as the slope in the individual sector values (not summed sectors) for jobs and wages over the most recent five years (as opposed to the status, which examines changes between two points in time, current versus five years prior to current), corrected by national trends in employment rates and average wages. We then calculated the average trend for jobs across all sectors, with the average weighted by the number of jobs in each sector. We calculated the average trend for wages across all sectors. We then averaged the wages and jobs average slopes to get the livelihoods trend.

5.7.2.3 Data

Status and trend

Sectors in each region (http://ohi-science.org/ohi-global/layers.html#sectors_in_each_region) (le_sector_weight): Proportion of jobs within each marine sector

Livelihood status scores (http://ohi-science.org/ohi-global/layers.html#livelihood_status_scores) (liv_status): Calculated using adjusted job and wage data in several marine sectors (data not updated since 2013)

Livelihood trend scores (http://ohi-science.org/ohi-global/layers.html#livelihood_trend_scores) (liv_trend): Calculated using change in adjusted job and wage data in several marine sectors (data not updated since 2013)

Pressure

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Nutrient pollution (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution) (po_nutrients): Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Pathogen pollution (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution) (po_pathogens): Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Genetic escapes (http://ohi-science.org/ohi-global/layers.html#genetic_escapes) (sp_genetic): Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Global Competitiveness Index (GCI) (http://ohi-science.org/ohi-global/layers.html#global_competitiveness_index_(gci)) (li_gci): Competitiveness in achieving sustained economic prosperity

Economic diversity (http://ohi-science.org/ohi-global/layers.html#economic_diversity) (li_sector_evenness): Sector evenness based on Shannon's Diversity Index calculated on the proportion of jobs in each sector as a measure of economic diversity

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.8 Natural products

In many countries the harvest of non-food natural products is important for local economies and can also be traded internationally. The sustainable harvest of these products is therefore an important component of a healthy ocean. This goal assesses the ability of countries to maximize the sustainable harvest of living marine resources, such as corals, shells, seaweeds, and fish for the aquarium trade. It does not include bioprospecting which focuses on potential (and largely unknowable and potentially infinite) value rather than current realized value, or non-living products such as oil and gas or mining products which by definition are not sustainable. We include six natural product categories: coral, ornamental fish, fish oil, inedible seaweeds and marine plants, shells, and sponges (Table 5.10). We did not have data for other key natural products such as wood from mangroves, and we excluded oils from mammals as they are widely seen as (currently) unsustainably harvested due to low mammal populations.

5.8.0.1 Current status

To determine the total production in tonnes for each product category we summed the products provided in the FAO commodities data (United Nations 2016a) for each category (Table 5.10).

Table 5.10. Natural product categories. List of FAO products included in each of the six natural product categories.

commodity	subcategory
corals	Coral and the like
fish oil	Alaska pollack oil, nei, Anchoveta oil, Capelin oil, Clupeoid oils, nei, Cod liver oil, Fish body oils, nei, Fish liver oils, nei, Gadoid liver oils, nei, Hake liver oil, Halibuts, liver oils, Herring oil, Jack mackerel oil, Menhaden oil, Pilchard oil, Redfish oil, Sardine oil, Shark liver oil, Shark oil, Squid oil, Pelagic fish oils, nei, Gadiformes, oil, nei, Demersal fish oils, nei, Alaska pollock, oil, nei
ornamentals	Ornamental saltwater fish, Ornamental fish nei

seaweeds	Agar agar in powder, Agar agar in strips, Agar agar nei, Carrageen (Chondrus crispus), Green laver, Hizikia fusiforme (brown algae), Kelp, Kelp meal, Laver, dry, Laver, nei, Other brown algae (laminaria, eisenia/ecklonia), Other edible seaweeds, Other inedible seaweeds, Seaweeds and other algae, unfit for human consumption, nei, Seaweeds and other algae, fit for human consumption, nei, Other red algae, Other seaweeds and aquatic plants and products thereof, Undaria pinnafitida (brown algae)
shells	Abalone shells, Miscellaneous corals and shells, Mother of pearl shells, Oyster shells, Sea snail shells, Shells nei, Trochus shells
sponges	Natural sponges nei, Natural sponges other than raw, Natural sponges raw

The status of each natural product category, P_c, was calculated as:

$$P_c = H_c * S_c, (Eq. 5.14)$$

where, H_c is the harvest level for a category relative to its own (buffered) peak reference point and S_c is the sustainability of that commodity.

For each commodity, we calculated H_c as the most recent harvest (in metric tons) per region relative to the maximum harvest ever achieved in that region, under the assumption that the maximum achieved at any point in time was likely the maximum possible. This creates a reference point internal to each country. We then established a buffer around this peak catch because we do not know whether it is sustainable. We rescaled these values from 0-1, with any value within 35% of the peak harvest set to 1.0.

Although we do not know actual sustainable levels of harvest, S_p, in each region, we estimated it based on exposure and risk components for each of the natural products commodities:

$$S_c = 1 - average(E_c + R_c), (Eq. 5.15)$$

where E_c is the exposure term and R_c is the risk term for each commodity.

The exposure term, E_c, is the ln-transformed intensity of harvest calculated as tonnes of harvest per km^2 of coral and/or rocky reef, depending on the product, relative to the global maximum. We ln transformed the harvest intensity scores because the distribution of values was highly skewed; because we do not know the true threshold of sustainable harvest, nearly all values would be considered highly sustainable without the log transformation.

The risk term, R_c, is based on whether a commodity has unsustainable harvest practices (i.e., the intensity of cyanide fishing for ornamental fish, and any harvest of corals since they are CITES protected species). Risk for all corals was set as 1 since species in both subclasses and multiple orders of extant corals in class Anthozoa are listed in CITES Appendices II and III (www.cites.org/eng/app/appendices.php). No sponges, algae or marine plants were listed in CITES and thus their risks were set at 0. Shells were also set as 0 since species were not listed individually in the FAO database and only one marine genus (*Tridacnidae* spp.) and one marine species (*Lithophaga lithophaga*) were identified in CITES Appendix II. Risk for ornamental fish was set based on assessments of cyanide or dynamite fishing by Reefs at Risk Revisited (www.wri.org/publication/reefs-at-risk-revisited) under the assumption that most ornamental fishes are harvested from coral reefs.

For the fish oil commodity sustainability was estimated using the fisheries score for the country. It is not possible to identify which of the species fished in the area are used to extract the fish oil. Therefore the estimate is based on all the stocks harvested.

To estimate the status score, x_{np}, for each region and year we took the weighted average of the individual product scores, P_c, such that:

$$x_{np} = \frac{\sum_{c=1}^{N} P_c * w_c}{N}, (Eq. 5.16)$$

where N is the number of product categories, c, that were harvested, and w_c is the relative contribution of each product to the overall status of the goal. w_c was calculated as the ratio of the maximum US dollar value for a product (from the smoothed, gap-filled data) across all years of data for the product, relative to the sum of maximum values for all products harvested in the country.

If a product had a peak value, but was missing a harvest value for that product in a given year, we used $w_c = 0$ during the aggregation for that year.

There are several important caveats about the natural product status model. First, our approach is supply (export) based. If declining demand for a natural product causes a decline in production, the producing country's score declines even if it could (sustainably) produce more. Similarly, if a country chose to reduce or halt production of a natural product in order to improve conservation or sustainability, its score will decline. Second, we do not have Maximum Sustainable Yield (MSY) estimates for any of the six natural products evaluated. When such estimates become available in the future they can easily be incorporated. These scenarios may lead to decreases in the score for a region despite maintenance or even improvement of the sustainable harvest of natural products; we instituted the 35% buffer around peak harvest (described above) as a way to help mitigate these potential issues. Finally, our estimate of the sustainability of many of the harvest practices is likely overly optimistic. For example, fishing for ornamental trade often employs unsustainable techniques such as cyanide fishing, but we have few data to inform such an estimate of sustainability in the status calculation for ornamental fish.

This model requires both harvest tonnes and value data. However, because of inconsistencies with how data are reported to FAO, there are many cases where harvest data but no value data are reported, and vice versa. We gapfilled these data because otherwise these mismatches in reporting would result in losing real data. We used a linear regression model to estimate missing tonnes or US dollar values (Frazier *et al.* 2016). For countries that never harvested a product, we assumed they cannot produce it and treat that as a 'no data' rather than a zero value. For countries that harvested a product at any point in time, empty values are treated as zeros since the country has the capacity to harvest that product.

5.8.0.2 Trend

Trend was calculated as described in section 4.3.1.

5.8.0.3 Data

Status and trend

Habitat extent of rocky reef (http://ohi-science.org/ohi-global/layers.html#habitat_extent_of_rocky_reef) (hab_rockyreef_extent): Area of rocky reef habitat

Blast fishing (http://ohi-science.org/ohi-global/layers.html#blast_fishing) (np_blast): Artisanal blast fishing

Poison fishing (http://ohi-science.org/ohi-global/layers.html#poison_fishing) (np_cyanide): Artisanal poison (cyanide) fishing

Relative natural product harvest value (http://ohi-science.org/ohi-global/layers.html#relative_natural_product_harvest_value) (np_harvest_product_weight): Relative importance of six marine commodities (coral, fish oil, seaweed and plants, shells, sponges, ornamental fish) within each region determined by dividing the max USD value (determined across most recent 10 years of data) of each product and dividing by the sum of the max USD values of all products

Natural product harvest (http://ohi-science.org/ohi-global/layers.html#natural_product_harvest) (np_harvest_tonnes): Yield in metric tonnes of six marine commodities (coral, fish oil, seaweed and plants, shells, sponges, ornamental fish)

Relative natural product harvest tonnes (http://ohi-science.org/ohi-global/layers.html#relative_natural_product_harvest_tonnes) (np_harvest_tonnes_relative): Tonnes of harvest of each commodity relative to maximum harvest (with 35% buffer) of the commodity within the region observed across years

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

UV radiation (http://ohi-science.org/ohi-global/layers.html#uv_radiation) (cc_uv): Pressure due to increasing frequency of UV anomolies

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_artisanal_fishing) (fp_art_lb): Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#low_bycatch_due_to_commercial_fishing) (fp_com_lb): Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_soft_bottom_habitat_destruction) (hd_subtidal_sb): Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling)

Chemical pollution (http://ohi-science.org/ohi-global/layers.html#chemical_pollution) (po_chemicals): Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Nutrient pollution (http://ohi-science.org/ohi-global/layers.html#nutrient_pollution) (po_nutrients): Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_management_effectiveness) (fp_mora_artisanal): Quality of management of small-scale fishing for artisanal and recreational purposes

Coastal protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(fishing_preservation)) (fp_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(fishing_preservation)) (fp_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

CITES signatories (http://ohi-science.org/ohi-global/layers.html#cites_signatories) (g_cites): Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signatories

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#coastal_protected_marine_areas_(habitat_preservation)) (hd_mpa_coast): Protected marine areas within 3nm of coastline (lasting special places goal status score)

EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(habitat_preservation)) (hd_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Measure of coastal ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_coastal_ecological_integrity) (species_diversity_3nm): Marine species condition (same calculation and data as the species subgoal status score) calculated within 3 nm of shoreline as a proxy for ecological integrity

Measure of ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_ecological_integrity) (species_diversity_eez): Marine species condition (species subgoal status score) as a proxy for ecological integrity

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.9 Sense of Place

This goal attempts to capture the aspects of the coastal and marine system that people value as part of their cultural identity. This definition includes people living near the ocean and those who live far from it but still derive a sense of identity or value from knowing particular places or species exist. This goal is calculated using two equally weighted subgoals: iconic species and lasting special places.

5.9.1 Iconic species (subgoal of sense of place)

Iconic species are those that are relevant to local cultural identity through their relationship to one or more of the following: 1) traditional activities such as fishing, hunting or commerce; 2) local ethnic or religious practices; 3) existence value; and 4) locally-recognized aesthetic value (e.g., touristic attractions/common subjects for art such as whales). Ultimately, almost any species can be iconic to someone, and so the intent with this goal was to focus on those species widely seen as iconic from a cultural or existence value (rather than a livelihoods or extractive reason). Habitat-forming species were not included, nor were species harvested solely for economic or utilitarian purposes (even though they may be iconic to a sector or individual).

5.9.1.1 Current status

The status of this sub-goal, x_{ico}, is the average of status scores of the iconic species in each region based on their IUCN Red List threat categories (IUCN 2016):

$$x_{ico} = \frac{\sum_{i=EX}^{LC} S_i \times w_i}{\sum_{i=EX}^{LC} S_i}, (Eq. 5.17)$$

where for each IUCN threat category i, S_i is the number of assessed species and w_i is the status (Table 5.3) following the methods described by Butchart et al. (2007). This formulation gives partial credit to species that still exist but are in one of the other threat categories. The reference point is to have the risk status of all assessed species as Least Concern (i.e., a goal score = 1.0). Species that have not been assessed or labeled as data deficient are not included in the calculation.

The list of iconic species was drawn from several data sources (http://ohi-science.org/ohi-global/layers#iucn_extinction_risk) (Section 6, IUCN extinction risk), but primarily from the World Wildlife Fund's global and regional lists for Priority Species (especially important to people for their health, livelihoods, and/or culture) and Flagship Species ('charismatic' and/or well-known). Many lists exist for globally important, threatened, endemic, etc. species, but in all cases it is not clear if or to what extent these species represent culturally iconic species. The World Wildlife Fund is the only data source that included cultural reasons for listing iconic species. Although, iconic species vary largely among regions, we include little regional information in our list (i.e., the same list is applied to nearly all regions). Our ultimate goal is to develop a more region-specific iconic species list.

5.9.1.2 Trend

We calculate trend using data the IUCN provides for current and past assessments of species, which we use to create a time series of average risk status for species within each region. Because IUCN assessments are generally infrequent for any given species, we derive the trend as the annual change in risk status for each species across the previous twenty years, rather than a five-year window typical of other goals, and include only taxa with two or more IUCN assessments within the past 20 years.

5.9.1.3 Data

Status and trend

IUCN extinction risk (http://ohi-science.org/ohi-global/layers.html#iucn_extinction_risk) (ico_spp_iucn_status): IUCN extinction risk category for iconic species located within each region

Pressure

Ocean acidification (http://ohi-science.org/ohi-global/layers.html#ocean_acidification) (cc_acid): Pressure due to increasing ocean acidification, scaled using biological thresholds

Sea surface temperature (http://ohi-science.org/ohi-global/layers.html#sea_surface_temperature) (cc_sst): Presure due to increasing extreme sea surface temperature events

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_artisanal_fishing) (fp_art_hb): Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP

High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers.html#high_bycatch_due_to_commercial_fishing) (fp_com_hb): Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP

Targeted harvest of cetaceans and marine turtles (http://ohi-science.org/ohi-global/layers.html#targeted_harvest_of_cetaceans_and_marine_turtles) (fp_targetharvest): Targeted harvest of cetaceans and marine turtles

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_fisheries_biodiversity_) (fp_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Commercial fishing management (http://ohi-science.org/ohi-global/layers.html#commercial_fishing_management) (fp_mora): Country scale regulations and management of commerical fishing

Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers.html#artisanal_fisheries_management_effectiveness) (fp_mora_artisanal): Quality of management of small-scale fishing for artisanal and recreational purposes

EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(fishing_preservation)) (fp_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

CITES signatories (http://ohi-science.org/ohi-global/layers.html#cites_signatories) (g_cites): Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signatories

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers.html#eez_protected_marine_areas_(habitat_preservation)) (hd_mpa_eez): Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ)

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Measure of ecological integrity (http://ohi-science.org/ohi-global/layers.html#measure_of_ecological_integrity) (species_diversity_eez): Marine species condition (species subgoal status score) as a proxy for ecological integrity

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.9.2 Lasting special places (subgoal of sense of place)

The lasting special places sub-goal focuses on geographic locations that hold particular value for aesthetic, spiritual, cultural, recreational or existence reasons (TRC 2004). This sub-goal is particularly hard to quantify. Ideally one would survey every community around the world to determine the top list of special places, and then assess how those locations are faring relative to a desired state (e.g., protected or well managed). The reality is that such lists do not exist. Instead, we assume areas that are protected indicate special places (i.e., the effort to protect them suggests they are important places). Clearly this is an imperfect assumption but in many cases it will be true.

The identification of protected areas does not indicate the proportion of special places in a region that are protected. To solve this problem we make two important assumptions. First, we assume that all countries have roughly the same percentage of their coastal waters and coastline that qualify as lasting special places. In other words, they all have the same reference target (as a percentage of the total area). Second, we assume that the target reference level is 30% of area protected (Hughes 2003).

5.9.2.1 Current status

We calculate the status of this goal as:

$$x_{lsp} = \frac{\left(\frac{\%_{CMPA}}{\%_{Ref_{CMPA}}} + \frac{\%_{CP}}{\%_{Ref_{CP}}}\right)}{2}, (Eq. 5.18)$$

where, $\%_{CMPA}$ is the proportion of coastal marine protected area, $\%_{CP}$ is the proportion of coastline protected, and $\%_{Ref} = 30$ for both measures.

We focus only on coastal waters (within 3 nautical miles of shore) for marine special places because we assume lasting special places are primarily in coastal areas. For coastlines, we focus only on the first 1-km-wide strip of land as a way to increase the likelihood that the area being protected by terrestrial parks is connected to the marine system in some way.

We use the United Nation's World Database on Protected Areas (WDPA) to identify protected areas (UNEP-WCMC 2015). The WDPA aggregates several key databases: IUCN's World Commission on Protected Areas, Global Marine Protected Areas, UNESCO World Heritage Marine sites, National Parks and Nature Reserves, and the United Nations List of Protected Places. In most cases the year of designation is listed for each protected area.

5.9.2.2 Trend

Trend was calculated as described in section 4.3.1.

5.9.2.3 Data

Status and trend

Inland coastal protected areas (http://ohi-science.org/ohi-global/layers.html#inland_coastal_protected_areas) (lsp_prot_area_inland1km): Protected areas located 1 km inland

Offshore coastal protected areas (http://ohi-science.org/ohi-global/layers.html#offshore_coastal_protected_areas) (lsp_prot_area_offshore3nm): Protected areas located 3nm offshore

Inland 1km area (http://ohi-science.org/ohi-global/layers.html#inland_1km_area) (rgn_area_inland1km): Inland area of OHI regions within 1km of shoreline

Offshore 3nm area (http://ohi-science.org/ohi-global/layers.html#offshore_3nm_area) (rgn_area_offshore3nm): Offshore area of OHI regions within 3nm of shoreline

Pressure

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers.html#intertidal_habitat_destruction) (hd_intertidal): Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction

Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers.html#subtidal_hardbottom_habitat_destruction) (hd_subtidal_hb): Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Nonindigenous species (http://ohi-science.org/ohi-global/layers.html#nonindigenous_species) (sp_alien): Measure of harmful invasive species

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_habitat_to_protect_habitat_biodiversity) (hd_habitat): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

5.10 Tourism and recreation

The tourism and recreation goal aims to capture the number of people, and the quality of their experience, visiting coastal and marine areas and attractions. Although coastal tourism industries can be important contributors to coastal economies, the tourism and recreation goal is assessed separately from its economic benefits, which are reported in the coastal livelihoods and economies goal. Few non-economic indicators of tourism and recreation exist at the global scale, consequently, we use employment in the tourism sector as a reasonable proxy measure for the total number of people engaged in coastal tourism and recreation activities. Employment within this sector should respond dynamically to the number of people participating in tourist activities, based on the assumption that the number of hotel employees, travel agents and employees of other affiliated professions will increase or decrease with changing tourism demand within different regions.

5.10.0.1 Current status

The model for the status of the tourism & recreation goal, x_{tr}, is:

$$x_{tr} = \frac{T_r}{T_{90th}}, (Eq. 5.19)$$

where, T_{90th} is the T_r value of the region value that corresponds to the 90th quantile, and:

$$T_r = E \times S \times W, (Eq. 5.20)$$

where, E is the proportion of employees directly involved in the travel and tourism industry, S is sustainability, and W is a penalty based on travel warnings issued by the US State Department.

Ideally there would be data available specifically for employment, E, in coastal tourism industries, however the best data available at a global scale reports the proportion of the workforce directly employed in tourism, not just coastal jobs (World Travel and Tourism Council, WTTC 2017). Because we do not know how employment patterns vary geographically within sectors for each region, we assume that the proportion employed in the tourism industry is the same in coastal areas as it is away from the coast, and thus E is the same whether applied solely to coastal areas or to the entire region.

The WTTC data include jobs for both leisure and business that are directly connected to the tourism industry, 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 tourism. 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. Regional applications of the Index can make use of better-resolved data and more direct measures of tourism, as has been done within the US West Coast (Halpern *et al.* 2014), where data for participation in coastal recreational activities across 19 different sectors were available.

Measures of sustainability are data from the World Economic Forum's (Schwab 2017b) Travel Tourism Competitiveness Index (TTCI). This index measures "the set of factors and policies that enable the sustainable development of the Travel & Tourism sector, which in turn, contributes to the development and competitiveness of a country".

The index is based on 14 pillars that are organized into four subindexes:

- Enabling Environment (general settings necessary for operating in a country)

    - Business Environment
    - Safety and Security
    - Health and Hygiene
    - Human Resources and Labour Market
    - ICT Readiness
- Travel and Tourism Policy and Enabling Conditions (specific policies or strategic aspects that impact the travel and tourism industry more directly)
    - Prioritization of Travel and Tourism
    - International Openness
    - Price Competitiveness
    - Environmental Sustainability
- Infrastructure (availability and quality of physical infrastructure of each economy)
    - Air Transport Infrastructure
    - Ground and Port Infrastructure
    - Tourist Service Infrastructure
- Natural and Cultural Resources (principal “reasons to travel”)
    - Natural Resources
    - Cultural Resources and Business Travel

The sustainability factor, S is calculated as the average of the 4 subindexes. Missing sustainability data were gapfilled using per capita GDP (World Bank data with gaps filled using CIA data) based on a linear regression model. For regions without per capita GDP data, remaining missing data were gapfilled using averages of UN geopolitical regions (https://github.com/OHI-Science/ohiprep/blob/master/src/LookupTables/rgn_georegions_wide_2013b.csv), (United Nations 2013d) with sustainability data.

Penalties, W were assigned based on travel warnings issued by the US State Department (Table 5.11).

Table 5.11. Travel warning penalties Penalties, W, based on level or US State Department travel warnings.

Travel warning	Penalty, W
Level 1:Exercise Normal Precautions	1 (no penalty)
Level 2: Exercise Increased Caution	1 (no penalty)
Level 3: Reconsider Travel	0.25
Level 4: Do Not Travel	0

5.10.0.2 Trend

Trend was calculated as described in section 4.3.1.

5.10.0.3 Data

Status and trend

Percent direct employment in tourism (http://ohi-science.org/ohi-global/layers.html#percent_direct_employment_in_tourism) (tr_jobs_pct_tourism): Percent direct employment in tourism

Tourism sustainability index (http://ohi-science.org/ohi-global/layers.html#tourism_sustainability_index) (tr_sustainability): Tourism Competitiveness Index (TTCI)

US State Department travel warnings (http://ohi-science.org/ohi-global/layers.html#us_state_department_travel_warnings) (tr_travelwarnings): US State Department travel warnings

Pressure

Sea level rise (http://ohi-science.org/ohi-global/layers.html#sea_level_rise) (cc_slr): Pressure due to rising mean sea level

Coastal chemical pollution (http://ohi-science.org/ohi-global/layers.html#coastal_chemical_pollution) (po_chemicals_3nm): Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution)

Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers.html#coastal_nutrient_pollution) (po_nutrients_3nm): Modeled nutrient pollution within EEZ based on fertilizer consumption

Pathogen pollution (http://ohi-science.org/ohi-global/layers.html#pathogen_pollution) (po_pathogens): Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution

Marine plastics (http://ohi-science.org/ohi-global/layers.html#marine_plastics) (po_trash): Global marine plastic pollution

Weakness of social progress (http://ohi-science.org/ohi-global/layers.html#weakness_of_social_progress) (ss_spi): Inverse of Social Progress Index scores

Weakness of governance (http://ohi-science.org/ohi-global/layers.html#weakness_of_governance) (ss_wgi): Inverse of World Governance Indicators (WGI) six combined scores

Resilience

Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers.html#management_of_waters_to_preserve_biodiversity) (po_water): Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions

Social Progress Index (http://ohi-science.org/ohi-global/layers.html#social_progress_index) (res_spi): Social Progress Index scores

Strength of governance (http://ohi-science.org/ohi-global/layers.html#strength_of_governance) (wgi_all): World Governance Indicators (WGI) six combined scores

6 Description of data layers

6.0.1 Tables describing data layers (Table 6.1) and sources (Table 6.2)

Table 6.1. Data layers of 2018 global OHI assessment A brief overview of all the data layers used to calculate the global OHI. The "Data layer" variable provides links to a full description of the data layer. The "Description" variable provides link/s to the data preparation scripts (when available). See Table 6.2 for a description of the data sources used to create these data layers.

Layer	Description	Dim
Artisanal fisheries opportunity (http://ohi-science.org/ohi-global/layers#ao_access)	The opportunity for artisanal and recreational fishing based on the quality of management of the small-scale fishing sector (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_mora_ao))	AO
Economic need for artisanal fishing (http://ohi-science.org/ohi-global/layers#ao_need)	Inverse of per capita purchasing power parity (PPP) adjusted gross domestic product (GDP): GDPpcPPP as a proxy for subsistence fishing need (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/ao/v2018/ao_need_data_prep.html))	AO
Habitat extent of coral (http://ohi-science.org/ohi-global/layers#hab_coral_extent)	Area of coral habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_coral))	CP
Habitat extent of seaice (http://ohi-science.org/ohi-global/layers#hab_seaice_extent)	Area of seaice (edge and shoreline) habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seaice/v2018/hab_seaice_dataprep.html))	CP
Habitat condition of coral (http://ohi-science.org/ohi-global/layers#hab_coral_health)	Current condition of coral habitat relative to historical condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_coral))	CP,
Habitat condition trend of coral (http://ohi-science.org/ohi-global/layers#hab_coral_trend)	Estimated trend in coral condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_coral))	CP,
Habitat condition of seaice (http://ohi-science.org/ohi-global/layers#hab_seaice_health)	Current condition of seaice habitat relative to historical condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seaice/v2018/hab_seaice_dataprep.html))	CP,
Habitat condition trend of seaice (http://ohi-science.org/ohi-global/layers#hab_seaice_trend)	Estimated trend in seaice condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seaice/v2018/hab_seaice_dataprep.html))	CP,
Habitat extent of mangrove (http://ohi-science.org/ohi-global/layers#hab_mangrove_extent)	Area of mangrove habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_mangrove/v2015))	CS,
Habitat extent of saltmarsh (http://ohi-science.org/ohi-global/layers#hab_saltmarsh_extent)	Area of saltmarsh habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_saltmarsh))	CS,
Habitat extent of seagrass (http://ohi-science.org/ohi-global/layers#hab_seagrass_extent)	Area of seagrass habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seagrass))	CS,
Habitat condition of mangrove (http://ohi-science.org/ohi-global/layers#hab_mangrove_health)	Current condition of mangrove habitat relative to historical condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_mangrove))	CS, CP
Habitat condition trend of mangrove (http://ohi-science.org/ohi-global/layers#hab_mangrove_trend)	Estimated trend in mangrove condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_mangrove/v2015))	CS, CP
Habitat condition of saltmarsh (http://ohi-science.org/ohi-global/layers#hab_saltmarsh_health)	Current condition of saltmarsh habitat relative to historical condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_saltmarsh))	CS, CP
Habitat condition trend of saltmarsh (http://ohi-	Estimated trend in saltmarsh condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_saltmarsh))	CS,

science.org/ohi-global/layers#hab_saltmarsh_trend)		CP
Habitat condition of seagrass (http://ohi-science.org/ohi-global/layers#hab_seagrass_health)	Current condition of seagrass habitat relative to historical condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seagrass))	CS, CP
Habitat condition trend of seagrass (http://ohi-science.org/ohi-global/layers#hab_seagrass_trend)	Estimated trend in seagrass condition (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_seagrass))	CS, CP
Chemical pollution trend (http://ohi-science.org/ohi-global/layers#cw_chemical_trend)	Trends in chemical pollution, based on commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution) within EEZ (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_chem/v2016))	CW
Nutrient pollution trend (http://ohi-science.org/ohi-global/layers#cw_nutrient_trend)	Trends in nutrient pollution, using fertilizer consumption as a proxy for nutrient pollution (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_land-based_nutrient/v2016))	CW
Pathogen pollution trend (http://ohi-science.org/ohi-global/layers#cw_pathogen_trend)	Trends in percent of population without access to improved sanitation facilities as a proxy for pathogen pollution (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_cw_pathogen/v2018/cw_sanitation_data_prep.html))	CW
Plastic trash trends (http://ohi-science.org/ohi-global/layers#cw_trash_trend)	Trends in trash estimated using improperly disposed of plastics (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/cw_trend_trash/v2016/cw_trend_trash_dataprep.html))	CW
Coastal chemical pollution (http://ohi-science.org/ohi-global/layers#po_chemicals_3nm)	Modeled chemical pollution within 3nm of coastline from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_chem/v2016))	CW pres
Coastal nutrient pollution (http://ohi-science.org/ohi-global/layers#po_nutrients_3nm)	Modeled nutrient pollution within EEZ based on fertilizer consumption (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_land-based_nutrient/v2016))	CW pres
Pathogen pollution (http://ohi-science.org/ohi-global/layers#po_pathogens)	Percent of population without access to improved sanitation facilities as a proxy for pathogen pollution (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_cw_pathogen/v2018/cw_sanitation_data_prep.html))	CW pres

Marine plastics (http://ohi-science.org/ohi-global/layers#po_trash)	Global marine plastic pollution (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/cw_pressure_trash/v2015))	CW pres
Economic status scores (http://ohi-science.org/ohi-global/layers#eco_status)	Calculated using corrected revenue data for several marine sectors (data not updated since 2013) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/le/v2018))	ECO
Economic trend scores (http://ohi-science.org/ohi-global/layers#eco_trend)	Calculated using change in revenue for several marine sectors (data not updated since 2013) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/le/v2018))	ECO
Sectors in each region (http://ohi-science.org/ohi-global/layers#le_sector_weight)	Proportion of jobs within each marine sector (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/le))	ECO
B/Bmsy estimates (http://ohi-science.org/ohi-global/layers#fis_b_bmsy)	The ratio of fish population abundance compared to the abundance required to deliver maximum sustainable yield (RAM and catch-MSY data) (data prep 1 (http://ohi-science.org/ohiprep_v2018/globalprep/fis/v2018/calculate_bbmsy.html), data prep 2 (http://ohi-science.org/ohiprep_v2018/globalprep/fis/v2018/RAM_CMSY_combine.html), data prep 3 (http://ohi-science.org/ohiprep_v2018/globalprep/fis/v2018/RAM_data_prep.html))	FIS
Fishery catch data (http://ohi-science.org/ohi-global/layers#fis_meancatch)	Mean commercial catch for each OHI region (averaged across years) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/fis/v2018/catch_data_prep.html))	FIS
Food provision weights (http://ohi-science.org/ohi-global/layers#fp_wildcaught_weight)	Proportion of wild caught fisheries relative to total food production (e.g., fisheries and mariculture) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/fp/v2018/FP_script.html))	FP
Habitat condition of softbottom (http://ohi-science.org/ohi-global/layers#hab_softbottom_health)	Current condition of softbottom habitat, based on demersal destructive fishing practices (e.g., trawling) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_prs_hd_subtidal_soft_bottom/v2018/hab_prs_soft_bottom_data_prep.html))	HAB

Habitat condition trend of softbottom (http://ohi-science.org/ohi-global/layers#hab_softbottom_trend)	Estimated change in softbottom condition, based on trends in demersal destructive fishing practices (e.g., trawling) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_prs_hd_subtidal_soft_bottom/v2018/hab_prs_soft_bottom_data_prep.html))	HAB
IUCN extinction risk (http://ohi-science.org/ohi-global/layers#ico_spp_iucn_status)	IUCN extinction risk category for iconic species located within each region (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/ico/v2018/ico_data_prep.html))	ICO
Livelihood status scores (http://ohi-science.org/ohi-global/layers#liv_status)	Calculated using adjusted job and wage data in several marine sectors (data not updated since 2013) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/le/v2018))	LIV
Livelihood trend scores (http://ohi-science.org/ohi-global/layers#liv_trend)	Calculated using change in adjusted job and wage data in several marine sectors (data not updated since 2013) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/le/v2018))	LIV
Inland coastal protected areas (http://ohi-science.org/ohi-global/layers#lsp_prot_area_inland1km)	Protected areas located 1 km inland (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	LSP
Offshore coastal protected areas (http://ohi-science.org/ohi-global/layers#lsp_prot_area_offshore3nm)	Protected areas located 3nm offshore (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	LSP
Inland 1km area (http://ohi-science.org/ohi-global/layers#rgn_area_inland1km)	Inland area of OHI regions within 1km of shoreline (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spatial))	LSP
Offshore 3nm area (http://ohi-science.org/ohi-global/layers#rgn_area_offshore3nm)	Offshore area of OHI regions within 3nm of shoreline (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spatial))	LSP

Inland coastal population (http://ohi-science.org/ohi-global/layers#mar_coastalpopn_inland25mi)	Total coastal population within 25 miles of coast (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/mar_prs_population/v2018/mar_prs_pop_dataprep.html))	MA
Mariculture harvest (http://ohi-science.org/ohi-global/layers#mar_harvest_tonnes)	Tonnes of mariculture harvest (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/mar/v2018/mar_dataprep.html))	MA
Mariculture sustainability score (http://ohi-science.org/ohi-global/layers#mar_sustainability_score)	Mariculture sustainability based on the Mariculture Sustainability Index (MSI) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/mar/v2018/mar_dataprep.html))	MA
Habitat extent of rocky reef (http://ohi-science.org/ohi-global/layers#hab_rockyreef_extent)	Area of rocky reef habitat (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_rockyreef))	NP
Blast fishing (http://ohi-science.org/ohi-global/layers#np_blast)	Artisanal blast fishing (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np_prs_poison_blast_fishing))	NP
Poison fishing (http://ohi-science.org/ohi-global/layers#np_cyanide)	Artisanal poison (cyanide) fishing (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np_prs_poison_blast_fishing))	NP
Relative natural product harvest value (http://ohi-science.org/ohi-global/layers#np_harvest_product_weight)	Relative importance of six marine commodities (coral, fish oil, seaweed and plants, shells, sponges, ornamental fish) within each region determined by dividing the max USD value (determined across most recent 10 years of data) of each product and dividing by the sum of the max USD values of all products (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np/v2018/np_dataprep.html))	NP
Natural product harvest (http://ohi-science.org/ohi-global/layers#np_harvest_tonnes)	Yield in metric tonnes of six marine commodities (coral, fish oil, seaweed and plants, shells, sponges, ornamental fish) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np/v2018/np_dataprep.html))	NP
Relative natural product harvest tonnes (http://ohi-science.org/ohi-global/layers#np_harvest_tonnes_relative)	Tonnes of harvest of each commodity relative to maximum harvest (with 35% buffer) of the commodity within the region observed across years (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np/v2018/np_dataprep.html))	NP
Ocean acidification (http://ohi-science.org/ohi-global/layers#cc_acid)	Pressure due to increasing ocean acidification, scaled using biological thresholds (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_oa/v2017/create_oa_layer.html))	pres
Sea level rise (http://ohi-science.org/ohi-global/layers#cc_slr)	Pressure due to rising mean sea level (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_slr/v2018/slr_layer_prep_v2.html))	pres
Sea surface temperature (http://ohi-science.org/ohi-global/layers#cc_sst)	Presure due to increasing extreme sea surface temperature events (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_sst/v2018/sst_layer_prep.rmd))	pres
UV radiation (http://ohi-science.org/ohi-global/layers#cc_uv)	Pressure due to increasing frequency of UV anomolies (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_uv/v2018/uv_dataprep.html))	pres

High bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers#fp_art_hb)	Pressure due to artisanal high bycatch fishing identified by discard tonnes and standardized by NPP (data prep 1 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/fishing_pressure_layers.html), data prep 2 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/npp.html))	pres
Low bycatch due to artisanal fishing (http://ohi-science.org/ohi-global/layers#fp_art_lb)	Pressure due to artisanal low bycatch fishing identified by reported and IUU tonnes and standardized by NPP (data prep 1 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/fishing_pressure_layers.html), data prep 2 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/npp.html))	pres
High bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers#fp_com_hb)	Pressure due to industrial high bycatch fishing identified by discard tonnes and standardized by NPP (data prep 1 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/fishing_pressure_layers.html), data prep 2 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/npp.html))	pres
Low bycatch due to commercial fishing (http://ohi-science.org/ohi-global/layers#fp_com_lb)	Pressure due to industrial low bycatch fishing identified by reported and IUU tonnes and standardized by NPP (data prep 1 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/fishing_pressure_layers.html), data prep 2 (http://ohi-science.org/ohiprep_v2018/globalprep/prs_fish/v2018/npp.html))	pres
Targeted harvest of cetaceans and marine turtles (http://ohi-science.org/ohi-global/layers#fp_targetharvest)	Targeted harvest of cetaceans and marine turtles (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_targetedharvest/v2018/targetharvest_dataprep.html))	pres
Intertidal habitat destruction (http://ohi-science.org/ohi-global/layers#hd_intertidal)	Coastal population density (25 mi from shore) as a proxy for intertidal habitat destruction (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/mar_prs_population/v2018/mar_prs_pop_dataprep.html))	pres
Subtidal hardbottom habitat destruction (http://ohi-science.org/ohi-global/layers#hd_subtidal_hb)	Presence of blast fishing as an estimate of subtidal hard bottom habitat destruction (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/np_prs_poison_blast_fishing/v2013))	pres
Subtidal soft bottom habitat destruction (http://ohi-science.org/ohi-global/layers#hd_subtidal_sb)	Pressure on soft-bottom habitats due to demersal destructive commercial fishing practices (e.g., trawling) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/hab_prs_hd_subtidal_soft_bottom/v2018/hab_prs_soft_bottom_data_prep.html))	pres
Chemical pollution (http://ohi-science.org/ohi-global/layers#po_chemicals)	Modeled chemical pollution within EEZ from commercial shipping traffic, ports and harbors, land-based pesticide use (organic pollution), and urban runoff (inorganic pollution) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_chem/v2016))	pres
Nutrient pollution (http://ohi-science.org/ohi-global/layers#po_nutrients)	Modeled nutrient pollution within 3nm of coastline based on fertilizer consumption (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_land-based_nutrient/v2016))	pres
Nonindigenous species (http://ohi-science.org/ohi-global/layers#sp_alien)	Measure of harmful invasive species (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_alien))	pres
Genetic escapes (http://ohi-science.org/ohi-global/layers#sp_genetic)	Introduced mariculture species (Mariculture Sustainability Index) as a proxy for genetic escapes (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/mar/v2018/mar_dataprep.html))	pres

Weakness of social progress (http://ohi-science.org/ohi-global/layers#ss_spi)	Inverse of Social Progress Index scores (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_res_spi/v2018/spi_dataprep.html))	pres
Weakness of governance (http://ohi-science.org/ohi-global/layers#ss_wgi)	Inverse of World Governance Indicators (WGI) six combined scores (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_res_wgi/v2018/WGI_dataprep.html))	pres
Management of habitat to protect fisheries biodiversity (http://ohi-science.org/ohi-global/layers#fp_habitat)	Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cbd_habitat))	resi
Commercial fishing management (http://ohi-science.org/ohi-global/layers#fp_mora)	Country scale regulations and management of commerical fishing (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_mora_ao))	resi
Artisanal fisheries management effectiveness (http://ohi-science.org/ohi-global/layers#fp_mora_artisanal)	Quality of management of small-scale fishing for artisanal and recreational purposes (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_mora_ao))	resi
Coastal protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers#fp_mpa_coast)	Protected marine areas within 3nm of coastline (lasting special places goal status score) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	resi
EEZ protected marine areas (fishing preservation) (http://ohi-science.org/ohi-global/layers#fp_mpa_eez)	Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	resi
CITES signatories (http://ohi-science.org/ohi-global/layers#g_cites)	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signatories (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cites_signatories/v2017))	resi
Management of mariculture to preserve biodiversity (http://ohi-science.org/ohi-global/layers#g_mariculture)	Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: mariculture related questions (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cbd_habitat))	resi
Mariculture Sustainability Index (http://ohi-science.org/ohi-global/layers#g_msi_gov)	Mariculture practice assessment criteria from the Mariculture Sustainability Index (MSI) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_mariculture_sustainability))	resi
Management of tourism to preserve biodiversity (http://ohi-science.org/ohi-global/layers#g_tourism)	Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: tourism related questions (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cbd_habitat))	resi
Management of habitat to protect habitat biodiversity (http://ohi-science.org/ohi-global/layers#hd_habitat)	Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: habitat related questions (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cbd_habitat))	resi
Coastal protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers#hd_mpa_coast)	Protected marine areas within 3nm of coastline (lasting special places goal status score) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	resi
EEZ protected marine areas (habitat preservation) (http://ohi-science.org/ohi-global/layers#hd_mpa_eez)	Protected marine areas within EEZ (lasting special places calculation applied to the entire EEZ) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/lsp/v2018/lsp_data_prep.html))	resi
Global Competitiveness Index (GCI) (http://ohi-science.org/ohi-global/layers#li_gci)	Competitiveness in achieving sustained economic prosperity (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_gci/v2018/res_gci_dataprep.html))	resi
Economic diversity (http://ohi-science.org/ohi-global/layers#li_sector_evenness)	Sector evenness based on Shannon's Diversity Index calculated on the proportion of jobs in each sector as a measure of economic diversity (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_li_sector_evenness))	resi
Management of waters to preserve biodiversity (http://ohi-science.org/ohi-global/layers#po_water)	Survey responses by country to the Convention on Biological Diversity (CBD) Third National Report: clean water management related questions (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/res_cbd_habitat))	resi
Social Progress Index (http://ohi-science.org/ohi-global/layers#res_spi)	Social Progress Index scores (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_res_spi/v2018/spi_dataprep.html))	resi
Measure of coastal ecological integrity (http://ohi-	Marine species condition (same calculation and data as the species subgoal status score) calculated within 3 nm of	resi

science.org/ohi-global/layers#species_diversity_3nm)	shoreline as a proxy for ecological integrity (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spp/v2018/spp_data_prep.html))	
Measure of ecological integrity (http://ohi-science.org/ohi-global/layers#species_diversity_eez)	Marine species condition (species subgoal status score) as a proxy for ecological integrity (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spp/v2018/spp_data_prep.html))	resi
Strength of governance (http://ohi-science.org/ohi-global/layers#wgi_all)	World Governance Indicators (WGI) six combined scores (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/prs_res_wgi/v2018/WGI_dataprep.html))	resi
Region areas based on EEZ boundaries (http://ohi-science.org/ohi-global/layers#rgn_area)	Area of Ocean Health Index regions modified from exclusive economic zones, weights used to calculate global score (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spatial))	spa
OHI region id (http://ohi-science.org/ohi-global/layers#rgn_global)	Subset of regions that are not deleted or disputed (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spatial))	spa
Regions (http://ohi-science.org/ohi-global/layers#rgn_labels)	Regions by type (eez, subocean, unclaimed) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spatial))	spa
Uninhabited regions (http://ohi-science.org/ohi-global/layers#uninhabited)	Regions with low and no number of inhabitants (also identifies Southern Islands) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/supplementary_information/v2018))	spa
Average species condition (http://ohi-science.org/ohi-global/layers#spp_status)	Overall measure of species condition based on IUCN status of species within each region (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spp/v2018/spp_data_prep.html))	SPI
Average species condition trend (http://ohi-science.org/ohi-global/layers#spp_trend)	Overall measure of species condition trends based on change in IUCN status of species within each region (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/spp/v2018/spp_data_prep.html))	SPI
Percent direct employment in tourism (http://ohi-science.org/ohi-global/layers#tr_jobs_pct_tourism)	Percent direct employment in tourism (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/tr/v2018/tr_data_prep.html))	TR
Tourism sustainability index (http://ohi-science.org/ohi-global/layers#tr_sustainability)	Tourism Competitiveness Index (TTCI) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/tr/v2018/tr_data_prep.html))	TR
US State Department travel warnings (http://ohi-science.org/ohi-global/layers#tr_travelwarnings)	US State Department travel warnings (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/tr/v2018/tr_data_prep.html))	TR

Coastal protection weights (http://ohi-science.org/ohi-global/layers#element_wts_cp_km2_x_protection)	Habitat extent multiplied by habitat protection rank for: coral, mangrove (offshore and inland 1km), saltmarsh, sea ice (shoreline), and seagrass (empty dataframe filled by functions.R in ohi-global) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/weighting_files))	weig
Carbon storage weights (http://ohi-science.org/ohi-global/layers#element_wts_cs_km2_x_storage)	Habitat extent multiplied by carbon storage capacity for: mangrove, saltmarsh, and seagrass (empty dataframe filled by functions.R in ohi-global) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/weighting_files))	weig
Habitat presence/absence (http://ohi-science.org/ohi-global/layers#element_wts_hab_pres_abs)	List of habitats in each region (empty dataframe filled by functions.R in ohi-global) (data prep (http://ohi-science.org/ohiprep_v2018/globalprep/weighting_files))	weig

Table 6.2. Data sources used to create data layers for 2018 global OHI assessment A brief overview of the data sources used to calculate the global OHI.

Reference	Description	Years	Resolution	Updated
Anderson (2018)	Methods: Data-limited stocks assessments			
AVISO (2018)	Net change in sea level during the time series	1993-2017	0.25 deg	y
Behrenfeld & Falkowski (1997)	Net Primary Productivity paper			
Bridgham *et al.* (2006)	Global salt marsh habitat extent and condition	1975-2007	National	n
Bruno & Selig (2007)	Global coral habitat extent and change in condition	2002,1980-2009,2006	0.5 km; 1 km; Sites (points)	n
Burke *et al.* (2011)	Presence of artisanal blast and poison (cyanide) fishing practices	2009	10 km	n
Burke *et al.* (2011)	Global coral habitat extent and change in condition	2002,1980-2009,2006	0.5 km; 1 km; Sites (points)	n
Cavalieri *et al.* (1996)	Sea ice change in extent, both edge and shoreline metrics	1979-2017	25 km	y
Center For International Earth Science Information Network-CIESIN-Columbia University (2017)	Raster data of human population	2005-2020	30 arcsec	y
CITES (2015)	Countries that signed the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	2017	National	n
Claus *et al.* (2012)	Land and ocean areas for OHI land and eez regions	2013	1 km	n
Convention on Biological Diversity (2005)	Convention on Biological Diversity: Data from Third National Report for regulation of alien species, habitat, mariculture, tourism, and water to preserve biodiversity	2005	National	n
Schwab (2017b)	Sustainability of the travel and tourism industry	2017	National	y
Dahl (2011)	Global salt marsh habitat extent and condition	1975-2007	National	n
France (2011)	La Rance (France) and Annapolis (Canada) tidal plants employment data	2003-2010	Points (sites)	n
Eionet (2008)	Global salt marsh habitat extent and condition	1975-2007	National	n
Eriksen *et al.* (2014)	Plastic trash pollution in ocean	2014	0.2 deg	n
ESRI (2010)	Land and ocean areas for OHI land and eez regions	2013	1 km	n
Feely *et al.* (2009)	Change in aragonite saturation state (ASS) levels	2005-2020	1 deg	y
Free (2017)	Maps of fish stock boundaries for the original RAM Myers stock-recruit database	2017	Stock	n
Halpern *et al.* (2008)	Modeled pollution from urban runoff from impervious surfaces	2000	1 km	n
Halpern *et al.* (2008)	Modeled pollution from pesticides	1990-2013	1 km (FAO data is National)	n
Halpern *et al.* (2008)	Modeled pollution from shipping and ports	2003/2011	1 km	n
Halpern *et al.* (2008)	Modeled N input from fertilizer use as a proxy for nutrient pollution	1990-2013	1 km (FAO data is National)	n

Halpern *et al.* (2008)	Global rocky reef habitat extent	2005	2 arcmin; Points	n
Halpern *et al.* (2008)	Global soft-bottom subtidal habitat extent	2001-2005	0.5 deg	n
Halpern *et al.* (2012)	WWF Priority and Flagship Species Lists	2011	Global; National	n
Halpern *et al.* (2012)	Land and ocean areas for OHI land and eez regions	2013	1 km	n
Halpern *et al.* (2015b)	Land and ocean areas for OHI land and eez regions	2013	1 km	n
Halpern *et al.* (2015a)	Modeled pollution from shipping and ports	2003/2011	1 km	n
Hamilton & Casey (2016)	Global mangrove habitat extent, from remote sensing and assessments	2000-2012	30m2, summarized to 500m2	n
Hemminga & Duarte (2000)	Seagrass geographical regions	2010	County	n
Homer *et al.* (2004)	Modeled pollution from urban runoff from impervious surfaces	2000	1 km	n
Hovila *et al.* (2013)	Anomalies in intensity of ultraviolet (UV) radiation	2005-2017	1 deg	y
('Bird species distribution maps of the world. version 7.0.' 2017)	Status of marine bird species	2017	National	y
IUCN (2018a)	IUCN Red List of threatened species by category; sub-population status for iconic species	1965-2018	National	y
IUCN (2018b)	IUCN spatial distribution	2018	Polygons rasterized to 0.5 deg	y
Jambeck *et al.* (2015)	Trends in mismanaged plastic waste for 2010 and projected for 2025 as a proxy for trash trends	2010-2025 (projected)	National	n
Joint Nature Conservation Committee (2004)	Global salt marsh habitat extent and condition	1975-2007	National	n
Kaufmann *et al.* (2010)	Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption			
Laffoley & Grimsditch (2009)	Carbon sequestration by habitat	2009	habitat	n
Lewis *et al.* (2017)	Location and area of marine and terrestrial protected areas manual			
Molnar *et al.* (2008)	The number and type of invasive and harmful invasive species in each marine ecoregion	2008	Ecoregion (sensu Spalding et al., 2007)	n
Mora *et al.* (2009)	Management effectiveness of the world's marine fisheries	2009	National	n
Mora *et al.* (2009)	Management effectiveness of artisanal fisheries	2009	National	n
New Zealand Ministry for the Environment (2007)	Global salt marsh habitat extent and condition	1975-2007	National	n
NOAA (2018)	Sea surface temperature anomalies	1982-2017	4 km	y
Index	Index measuring quality of life indicators	2014-2017	National	y
RAM (2017)	Stock assesment scores data	1950-2016	Stock	y
O'Connor *et al.* (2009)	Jobs based on number of whale watchers in a country and a regional average number of whale watchers per employee. Includes all marine mammal watching.	1998-2008	National	n
O'Connor *et al.* (2009)	Total revenue from marine mammal watching	1998-2008	National	n
O'Malley	Net Primary Productivity website	2003-2015	0.083 deg	y
Oostendorp & Freeman (2012)	Occupations within commercial fishing, ports and harbors, ship and boat building, tourism, and transportation and shipping	1989-2008	National	n
Ricard *et al.* (2012)	Stock assesment RAM data, paper			
Schutte *et al.* (2010)	Global coral habitat extent and change in condition	2002,1980-2009,2006	0.5 km; 1 km; Sites (points)	n
Schwab (2017a)	Composite measure of 12 aspects of economic competitiveness	2007-2017	National	y
Short *et al.* (2011)	Global seagrass habitat extent and change in condition	1975-2010	1 km, National	n
Stern *et al.* (2018)	Methods: Index measuring quality of life indicators			

Tallis *et al.* (2011)	Ranks of coastal protection provided by habitats	2011	habitat	n
Thorbourne (2011)	La Rance (France) and Annapolis (Canada) tidal plants employment data	2003-2010	Points (sites)	n
Trujillo (2008)	Mariculture Sustainability Index (MSI): traceability and code of practice, fishmeal use, waste treatment, and seed and larvae origin indicators	1994-2003	National	n
IUCN (2018)	Location and area of marine and terrestrial protected areas data	1819-2018	Shapefile	y
UNEP-WCMC & Short (2005)	Global seagrass habitat extent and change in condition	1975-2010	1 km, National	n
United Nations (2013a)	Total revenue from commercial marine fishing	1997-2007	National	n
United Nations (2013c)	Revenue of Aquarium Trade Fishing derived from commodities database	1984-2009	National	n
United Nations (2013b)	Total revenue from mariculture production of marine species	1977-2011	National	n
United Nations (2016d)	Modeled pollution from pesticides	1990-2013	1 km (FAO data is National)	n
United Nations (2016d)	Modeled N input from fertilizer use as a proxy for nutrient pollution	1990-2013	1 km (FAO data is National)	n
United Nations (2017)	Export tonnes and value (US dollars) and of coral, ornamental fish, fish oil, sponges, shells, and seaweeds and plants	1976-2015	National	y
United Nations (2018b)	Catch statistics for cetaceans and marine turtles	1950-2016	National	y
United Nations (2018a)	Production of finfish and invertebrates	1950-2016	National	y
United Nations personal communication (2011)	Global Number of Fishers, commercial fishing	1990-2008	National	n
United Nations personal communication (2011)	Global Number of Fishers, aquaculture	1993-2008	National	n
United Nations (2012)	Total revenue from marine renewable energy	1990/2001-2010/2008	National	n
United Nations (2007)	Mangrove condition	1980/1990/2000/2005	Country	n
State (2018)	Travel warnings issued by the US State Department	2015-2018	National	y, source updated how they report data
Watson & Tidd (2018)	Fisheries catch by species and gear type (tonnes/km2)	1950-2015	0.5 deg	y
Waycott *et al.* (2009)	Global seagrass habitat extent and change in condition	1975-2010	1 km, National	n
WHO-UNICEF (2017)	Percent population without access to improved sanitation facilities	2000-2015	National	n, source updated how they report data
World Bank (2014a)	Gross Domestic Product; Adjustment to all revenue data layers to factor out global economic fluctuations, in 2012 $USD	1960-2012	National	n
World Bank (2017)	Per capita purchasing power parity (PPP) adjusted gross domestic product (GDP): GDPpcPPP	1990-2017	National	y
World Bank (2014b)	Number of people aged 15 and older who could contribute to the production of goods and services	1990-2011	National	n
World Bank (2016)	Census populations for countries	1990-2012	National	n
World Bank (2014c)	Percent of the labor force unemployed but able to and looking for work	1990-2011	National	n
World Bank (2018)	Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption	1996-2016	National	y
WTTC (2013)	Total contribution of tourism to employment	1988-2012	National	n
WTTC (2013)	Total tourism revenue by country, adjusted by country's relative proportion of coastal area	1998-2012	National	n
WTTC (2017)	Employment directly linked to travel and tourism sectors (hotels, transportation, services)	1988-2017	National	y

Martell & Froese (2013)	Methods: Data-limited stocks assessments			
Rosenberg *et al.* (2014)	Methods: Data-limited stocks assessments			
Wikipedia	Population by region	2018	National	y

6.1 Artisanal fisheries management effectiveness

fp_mora_artisanal (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_mora_artisanal.csv)

Resilience

Category: ecological/regulatory

Subcategory: fishing

See **Artisanal fisheries opportunity** data layer for information about data and methods.

Units

scaled 0-1

6.2 Artisanal fisheries opportunity

ao_access (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/ao_access.csv)

This layer represents the opportunity for artisanal and recreational fishing in each country based on the quality of management of the small-scale fishing sector. Global data were extracted from Mora et al. (2009), Figure S4. Figure S4 is based on two expert opinion survey questions related to artisanal and recreational fishing (classified as small-scale fishing; presented in Table S5). Overall scores for small-scale fisheries management for each country are based on a scale of 0 to 100, with higher scores representing better management. These values were then rescaled (using a maximum value of 100 and minimum value of 0) to range between 0 and 1 for each OHI region.

Questions from Mora et al. that were used to evaluate access to artisanal scale fishing:

If recreational fishing exists to any extent, which of the following apply?

- Are recreational fishermen required to have a fishing license? Y/N
- Are there regulations to the size of fish caught? Y/N
- Are there regulations to the number of fish caught? Y/N
- Are there regulations to the number of fishermen allowed to fish? Y/N
- Are there statistics being collected for this sort of fishing? Y/N

If artisanal fishing exists to any extent, which of the following apply?

- Are there regulations to the size of fish caught? Y/N
- Are there regulations to the number of fish caught? Y/N
- Are there regulations to the number of fishermen allowed to fish? Y/N
- Are there statistics being collected for this sort of fishing? Y/N

Units

scaled 0-1

6.3 Average species condition

spp_status (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/spp_status.csv)

See Species goal for calculations.

These are the status data for the species subgoal, calculated using the species model. These data describe the average condition of species within each region based on risk status from the IUCN Red List of Threatened Species (http://www.iucnredlist.org/ (http://www.iucnredlist.org/)) and BirdLife International (http://datazone.birdlife.org (http://datazone.birdlife.org)) data.

We include only species from comprehensively assessed groups (groups with >90% of species assessed) to help control for sampling bias. We found that some regions (e.g., Atlantic) had assessments for a much larger proportion of species than other regions, but this problem was less pronounced when we only included comprehensively assessed species.

These data incorporate regional IUCN assessment information when possible (i.e., when a species' IUCN status varies geographically).

Units

status score

6.4 Average species condition trend

spp_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/spp_trend.csv)

See Species goal for calculations.

These are the trend data for the species subgoal. These data describe changes in species condition within each region based on historical changes in risk status from IUCN Red List of Threatened Species http://www.iucnredlist.org/ (http://www.iucnredlist.org/)).

Units

trend score

6.5 B/Bmsy estimates

fis_b_bmsy (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fis_b_bmsy.csv)

Status of global fish stocks based on B/Bmsy values (the ratio of population biomass compared to the biomass required to deliver maximum sustainable yield). We preferentially used B/Bmsy estimates from formal stock assessments from the RAM Legacy Database http://ramlegacy.org/ (http://ramlegacy.org/). We assigned the stocks to OHI and FAO regions using Free (2017) spatial data describing the range of each stock. When a stock was missing the most recent years of data, we used linear models of the previous years of data to estimate the missing years.

When RAM data were unavailable, we use the data-limited catch-MSY model (Martell & Frowese 2012) to estimate B/Bmsy values using yearly fish catch reconstruction data. For the catch-MSY model, we defined a stock as a species caught within an FAO major fishing area (www.fao.org/fishery/area/search/en). This definition of a stock eliminated all taxa not identified to species level. This approach assumes that stocks are defined by FAO region, which we know is often not true because multiple stocks of the same species can exist within an FAO region and some stocks cover multiple FAO regions. However, this assumption is necessary without range maps of stocks. The catch data were summed for each species/FAO region/year, and the catch-MSY model was applied to each stock and FAO region to estimate B/Bmsy.

Units

B/Bmsy

6.6 Blast fishing

np_blast (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/np_blast.csv)

Reefs at Risk Revisited (Burke et al. 2007) recorded the global presence of destructive artisanal blast fishing based on survey observations and expert opinion. We reclassified the log-scale scoring system for the blast rasters so 0 = 0, 100 = 1, 1000 = 2. The mean raster score was then determined for each OHI region. The blast values for each region were then summed to get the total.

Units

scaled 0-1

6.7 Carbon storage weights

element_wts_cs_km2_x_storage (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/element_wts_cs_km2_x_storage.csv)

This layer describes the relative value of the habitats in each region to carbon storage, and is calculated by multiplying the habitat extent (km^2) in each region by the amount of carbon the habitat sequesters (Laffoley & Grimsditch 2009).

Data is generated in ohi-global/eez/conf/functions.R.

These data are called internally by ohicore functions (see: conf/config.R to see how these data are specified) to weight the data used to calculate pressure and resilience values.

Table 6.3. Carbon storage weights

Habitat	Carbon storage
Mangrove	139
Saltmarsh	210
Seagrass	83

Units

extent*carbon_storage

6.8 Chemical pollution

po_chemicals (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_chemicals.csv)

Pressure

Category: ecological

Subcategory: pollution

This pressure layer is calculated using modeled data for land-based organic pollution (pesticide data), land-based inorganic pollution (using impermeable surfaces as a proxy), and ocean pollution (shipping and ports). These global data are provided at ~1km resolution, with raster values scaled from 0-1 (Halpern et al. 2008, 2015). To obtain the final pressure values, the three raster layers were summed (with cell values capped at 1).

6.8.0.1 Land-based organic pollution

Data were calculated using modeled plumes of land-based pesticide pollution that provide intensity of pollution at $1km^2$ resolution (Halpern et al. 2008).

Organic pollution was estimated from FAO data on annual country-level pesticide use (http://faostat3.fao.org/faostat-gateway/go/to/browse/R/*/E (http://faostat3.fao.org/faostat-gateway/go/to/browse/R/*/E)), measured in metric tons of active ingredients. FAO uses survey methods to measure quantities of pesticides applied to crops and seeds in the agriculture sector, including insecticides, mineral oils, herbicides, fungicides, seed treatments insecticides, seed treatments fungicides, plant growth regulators and rodenticides. Missing values were estimated by regression between fertilizer and pesticides when possible, and when not possible with agricultural GDP as a proxy. Data were summed across all pesticide compounds and reported in metric tons. Upon inspection the data included multiple 0 values that are most likely data gaps in the time-series, so they were treated as such and replaced with NA. In addition, regions with only 1 data point and regions where the most recent data point was prior to 2005 were excluded. Uninhabited countries were assumed to have no pesticide use and thus excluded.

Region-level pollution values were then dasymetrically distributed over a region's landscape using global landcover data from 2009, derived from the MODIS satellite data at ~500m resolution. These values were then aggregated by ~140,000 global basins, and diffusive plumes were modeled from each basin's pourpoint. The final non-zero plumes (about ~76,000) were aggregated into ~1km Mollweide (wgs84) projection rasters to produce a single plume-aggregated pollution raster.

These raw values were then ln(X+1) transformed and normalized to 0-1 by dividing by the 99.99th quantile of raster values across all years. The zonal mean was then calculated for each region.

6.8.0.2 Land-based inorganic pollution

These data are from Halpern et al. (2008, 2015), and available from Knowledge Network for Biocomplexity (KNB, https://knb.ecoinformatics.org/#view/doi:10.5063/F19021PC, rescaled_2013_inorganic_mol (https://knb.ecoinformatics.org/#view/doi:10.5063/F19021PC,%20rescaled_2013_inorganic_mol)). Non-point source inorganic pollution was modeled with global 1 km^2 impervious surface area data http://www.ngdc.noaa.gov/dmsp/ (http://www.ngdc.noaa.gov/dmsp/) under the assumption that most of this pollution comes from urban runoff. These data will not capture point-sources of pollution or nonpoint sources where paved roads do not exist (e.g., select places in developing countries). Values were aggregated to the watershed and distributed to the pour point (i.e., stream and river mouths) for the watershed with raster statistics (i.e., aggregation by watershed).

6.8.0.3 Ocean pollution (shipping lanes, ports)

These data are from Halpern et al. (2015), and available from the Knowledge Network for Biocomplexity (KNB, https://knb.ecoinformatics.org/#view/doi:10.5063/F1DR2SDD (https://knb.ecoinformatics.org/#view/doi:10.5063/F1DR2SDD), rescaled_2013_one_ocean_pollution_mol). Ocean-based pollution combines commercial shipping traffic data and port data.

Shipping data was obtained from two sources: (1) Over the past 20 years, 10-20% of the vessel fleet has voluntarily participated in collecting meteorological data for the open ocean, which includes location at the time of measurement, as part of the Volunteer Observing System (VOS). (2) In order to improve maritime safety, in 2002 the International Maritime Organization SOLAS agreement required all vessels over 300 gross tonnage (GT) and vessels carrying passengers to equip Automatic Identification System (AIS) transceivers, which use the Global Positioning System (GPS) to precisely locate vessels.

Port data was based on the volume (measured in tonnes) of goods transported through commercial ports as a proxy measure of port traffic. Total cargo volume data by port was collected from regional and national statistical organizations, and from published port rankings.

Units

scaled 0-1

6.9 Chemical pollution trend

cw_chemical_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cw_chemical_trend.csv)

See description for **Chemical pollution** layer.

The inverse of the pressure data (1 - Coastal chemical pollution) was used to estimate chemical trends for the clean water goal. The proportional yearly change in chemical pressure values were estimated using a linear regression model of the most recent five years of data (i.e., slope divided by value from the earliest year included in the regression model). The slope was then multiplied by five to get the predicted change in 5 years.

The only layer with yearly data was land-based organic pollution (pesticide data). The land-based inorganic pollution (using impermeable surfaces as a proxy) and ocean pollution (shipping and ports) remained the same across years.

Units

trend

6.10 CITES signatories

g_cites (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/g_cites.csv)

Resilience

Category: ecological/regulatory

Subcategory: goal

Contracting parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, http://www.cites.org/eng/disc/parties/alphabet.php (http://www.cites.org/eng/%20disc/parties/alphabet.php)). The Convention is an international agreement between governments that aims to ensure that any international trade in plants and animals "does not threaten their survival." All countries party to the Convention are given full credit for membership (territories are given the same score as their administrative countries); those countries that are not contracting parties are given no credit (score = 0).

Units

0 or 1

6.11 Coastal chemical pollution

po_chemicals_3nm (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_chemicals_3nm.csv)

Pressure

Category: ecological

Subcategory: pollution

See description for **Chemical pollution**.

Methods follow those described for the **Chemical pollution** layer. However, the rescaled data were clipped to include only pixels within 3nm offshore, and the zonal mean for each region was calculated using this subset of data.

For the clean waters goal calculations, the inverse of the pressure values is used (1 minus chemical pressure).

Units

scaled 0-1

6.12 Coastal nutrient pollution

po_nutrients_3nm (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_nutrients_3nm.csv)

Pressure

Category: ecological

Subcategory: pollution

See description for **Nutrient pollution**.

Methods follow those described for the **Nutrient pollution** layer. However, the rescaled data were clipped to include only pixels within 3nm offshore, and the zonal mean for each region was calculated using this subset of data.

For the clean waters goal calculations, the inverse of the pressure values is used (1 minus nutrient pressure).

Units

scaled 0-1

6.13 Coastal protected marine areas (fishing preservation)

fp_mpa_coast (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_mpa_coast.csv)

Resilience

Category: ecological/regulatory

Subcategory: fishing

These data are calculated using the lasting special places status subgoal model using total marine protected area (km^2) within 3 nm offshore (see **Offshore coastal protected areas** layer for information about the data). Following the lasting special places model, a reference point of 30% is used, such that any region with 30%, or more, protected area receives a score of 1.

Units

scaled 0-1

6.14 Coastal protected marine areas (habitat preservation)

hd_mpa_coast (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_mpa_coast.csv)

Resilience

Category: ecological/regulatory

Subcategory: habitat

See **Coastal protected marine areas (fishing preservation)** for information about this layer.

Units

scaled 0-1

6.15 Coastal protection weights

element_wts_cp_km2_x_protection (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/element_wts_cp_km2_x_protection.csv)

This layer describes the relative value of the habitats in each region to coastal protection, and is calculated by multiplying the habitat extent (km^2) in each region by the habitat protection rank.

Data is generated in ohi-global/eez/conf/functions.R.

These data are called internally by ohicore functions (see: conf/config.R to see how these data are specified) to weight the data used to calculate pressure and resilience values.

Table 6.4. Coastal protection ranks

Habitat	Protection rank
Coral	4
Mangrove	4

Seaice (shoreline)	4
Saltmarsh	3
Seagrass	1

Units

extent*rank_protection

6.16 Commercial fishing management

fp_mora (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_mora.csv)

Resilience

Category: ecological/regulatory

Subcategory: fishing

These data describe the current effectiveness of fisheries management regimes along 6 axes (Mora et al. 2009): scientific robustness, policy transparency, implementation capacity, subsidies, fishing effort, and foreign fishing. All countries with coastal areas were assessed through a combination of surveys, empirical data and enquiries to fisheries experts. For each OHI reporting region, scores for each category were rescaled between 0 and 1 using the maximum possible value for each category and then the average score of all 6 categories was used as the overall fisheries management effectiveness score.

Units

scaled 0-1

6.17 Economic diversity

li_sector_evenness (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/li_sector_evenness.csv)

Resilience

Category: social

Sector evenness was measured using Shannon's Diversity Index, a common measure of ecological and economic diversity that has been applied previously to economic sectors (Attaran 1986). The Diversity Index is computed as H'/H_{max} where:

$$H' = \sum_{i}^{z} f_i * \ln(f_i), (Eq. 6.1)$$

and Z is the total number of sectors, fi is the frequency of the ith sector (the probability that any given job belongs to the sector), and $H_{max} = \ln Z$.

Units

scaled 0-1

6.18 Economic need for artisanal fishing

ao_need (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/ao_need.csv)

These data are used to estimate the need for artisanal fishing opportunities given teh purchasing power parity adjusted per capita gross domestic product (ppppcgdp) in "constant" USD (World Bank, http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD (http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD)). The World Bank defines gdp as the gross value of all resident producers in the economy plus product taxes and minus and subsidies not included in the value of the products. The gdp is adjusted by population size to get per capita output and by purchasing power parity (ppp) to account for the difference in exchange rates between countries. ppppcgdp data were rescaled to values between zero and one by taking the natural log of the values and dividing by the 99th quantile value across all years/regions (2005 to most recent year).

When a region is missing some years of data, a within region linear model is used to estimate the missing values.

This is actually a measure of prosperity, but it is converted to need in the artisanal opportunities goal model (1 minus ppppcgdp).

Units

scaled 0-1

6.19 Economic status scores

eco_status (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/eco_status.csv)

This layer provides calculated status values for the economies subgoal. Economies is calculated using revenue data from marine sectors.

Note: These data are no longer supported. Consequently, this layer was last updated in 2013, and this goal will no longer be updated with these data.

Economies status is calculated as: (cur_base_value / ref_base_value) / (cur_adj_value / ref_adj_value)

Where, cur_base_value is the most recent revenue values for each sector/region, and ref_base_value is the earliest year of revenue data for each sector/region. These values are adjusted by dividing by the GDP of corresponding region/year to control for larger economic trends. National GDP data were obtained from the World Bank (http://data.worldbank.org/indicator/ NY.GDP.MKTP.CD (http://data.worldbank.org/indicator/%20NY.GDP.MKTP.CD)). For the three EEZs that fall within the China region (China, Macau, and Hong Kong), we combined the values using a population-weighted average.

This layer includes yearly data for revenue in commercial fishing, aquarium trade fishing, mariculture, marine mammal watching, marine renewable energy, and, tourism. The data sources and methods for each sector are described below.

6.19.0.1 Aquarium trade fishing

To approximate revenue from aquarium fishing we used export data from the FAO Global Commodities database for 'Ornamental fish' for all available years. We used data from two of the four subcategories listed, excluding the subcategory 'Fish for culture including ova, fingerlings, etc.' because it is not specific to ornamental fish, and the subcategory 'Ornamental freshwater fish' because it is not from marine systems.

6.19.0.2 Commercial fishing

Revenue data for commercial fishing were obtained from FAO's FishStat database, which provides yearly dollar values of commercial fisheries production for marine, brackish and freshwater species starting in 1950 and updated yearly. To isolate production values attributable to marine and brackish aquaculture, data pertaining to freshwater species were omitted. This species classification process was very time consuming as each species had to be queried individually per year. There was little year-to year variation, and thus data were extracted in 5 year increments, providing data for 1997, 2002 and 2007.

6.19.0.3 Mariculture

Data on revenues from marine aquaculture were derived from FAO's FishStat database, which includes country-level data on total production values for marine, brackish, and freshwater species beginning in 1984 and updated yearly. To isolate production values attributable to marine and brackish aquaculture, data pertaining to freshwater species were omitted. This species classification process was very time consuming as each species had to be queried individually per year. There was little year-to year variation, and thus data were extracted in 5 year increments, providing data for 1997, 2002 and 2007.

6.19.0.4 Marine mammal watching

IFAW provides country-level data on total expenditures (including direct and indirect) attributable to the whale watching industry (O'Connor et al. 2009). Here, total expenditures are used as a close proxy for total revenue. We used total expenditure data (direct and indirect expenditures) to avoid using a literature derived multiplier effect. When IFAW reported "minimal" revenue from whale watching, we converted this description to a 0 for lack of additional information. For countries with both marine and freshwater cetacean viewing, we adjusted by the proportion of marine revenue as described for the jobs dataset.

6.19.0.5 Marine renewable energy

The United Nations Energy Statistics Database provides production data, in kilowatt-hours (KWh), for tidal and wave electricity. However, only two countries, France and Canada, have high enough levels of production to be reported in this data source. For Canada, production data were replaced with production data (Gross Megawatt hours per year from 1995-2010) provided directly from the Annapolis tidal power plant because the plant provided a longer time series (Ruth Thorbourne, personal communication, Aug 9, 2011). To convert production data into revenue, production values were multiplied by average yearly prices of electricity per KWh specific to Canada and France, provided by the US Energy Information Administration (http://www.eia.gov/emeu/international/elecprii.html (http://www.eia.gov/emeu/international/elecprii.html); updated June 2010) after conversion to 2010 USD. Some of the production data could not be used because there were no available electricity price data to convert production into revenue, truncating our time series.

6.19.0.6 Tourism

WTTC reports dollar values of visitor exports (spending by foreign visitors) and domestic travel and tourism spending; combining these two data sets creates a proxy for total travel and tourism revenues. WTTC was chosen as the source for tourism revenue data because of the near-complete country coverage, the yearly time series component starting in 1988 and updated yearly, and the inclusion of both foreign and domestic expenditures. This dataset lumps inland and coastal/marine revenues, and so was adjusted by the percent of a country's population within a 25 mile inland coastal zone. We included no projected data. We used total contribution to GDP data (rather than direct contribution to GDP) to avoid the use of literature derived multiplier effects.

Units

status 0-100

6.20 Economic trend scores

eco_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/eco_trend.csv)

See **Economic status scores** layer for more information about data and methods.

This layer provides calculated trend values for the economies subgoal. Economies is calculated using revenue data from marine sectors.

Note: These data are no longer supported. Consequently, this layer was last updated in 2013, and this goal will no longer be updated with these data.

Units

trend -1 to 1

6.21 EEZ protected marine areas (fishing preservation)

fp_mpa_eez (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_mpa_eez.csv)

Resilience

Category: ecological/regulatory

Subcategory: fishing

These data are calculated using the lasting special places status subgoal model (except this calculation is based on the entire eez region vs. 3 nm offshore), using the total marine protected area (km^2) within the offshore eez region (see the **Offshore coastal protected areas** layer for information about the data). Following to the lasting special places model, a reference point of 30% is used, such that any region with 30%, or more, protected area receives a score of 1.

Units

scaled 0-1

6.22 EEZ protected marine areas (habitat preservation)

hd_mpa_eez (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_mpa_eez.csv)

Resilience

Category: ecological/regulatory

Subcategory: habitat

See **EEZ protected marine areas (fishing preservation)** for information about this layer.

Units

scaled 0-1

6.23 Fishery catch data

fis_meancatch (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fis_meancatch.csv)

Fisheries catch data were averaged across years (e.g., catch values are the same across years within a taxa/region) for each OHI region and taxon. These values were used to weight the stock status scores (derived from B/Bmsy values) in the fisheries model. Yearly catch data (tonnes) from the Global Fisheries Landings V3.0 (http://metadata.imas.utas.edu.au/geonetwork/srv/eng/metadata.show?uuid=ff1274e1-c0ab-411b-a8a2-5a12eb27f2c0) (Global Fisheries Landings V3.0, Watson 2018) is reported at 0.5 degree resolution for taxonomic levels range from species to class to "Miscellaneous not identified". Tonnes of catch for each taxon and year were summed within each OHI region, and then the average catch across years (1980 to present) was determined for each taxon and region.

Units

tonnes

6.24 Food provision weights

fp_wildcaught_weight (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_wildcaught_weight.csv)

To weight the relative contributions of fisheries and mariculture to the food provision goal, we calculate the tonnes of fisheries production relative to the total tonnes of food production from fisheries and mariculture.

Units

proportion

6.25 Genetic escapes

sp_genetic (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/sp_genetic.csv)

Pressure

Category: ecological

Subcategory: nonindigenous species

This layer represents the potential for harmful genetic escapement based on whether the species being cultured is native or introduced. Data come from the Mariculture Sustainability Index (MSI, Trujillo 2008). In the MSI analysis native species receive the highest score (10), while foreign and introduced species receive the lowest (1) on the premise of potential impacts to local biodiversity if these species were to escape. Use of native but non-local species were scored intermediately based on the assumption that potentially negative alterations to genetic biodiversity occur from non-local sources as well, but to a lower degree. Genetic 'pollution' can arise when larvae, spats or seeds escape from poorly managed hatcheries, making native species vulnerable to outbreeding depressions and/or genetic bottlenecks. The MSI reports data for 359 country-species combinations (with 53 countries represented). Where multiple scores exist for a country the weighted average of all scores (0-10) is used. All country scores were then rescaled from 0 to 1, using the maximum raw score of 10 and minimum of 1. Countries that were not analyzed by Trujillo did not receive a score and this pressure layer falls out of their analyses.

Units

scaled 0-1

6.26 Global Competitiveness Index (GCI)

li_gci (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/li_gci.csv)

Resilience

Category: social

The World Economic Forum's Global Competitiveness Index (GCI) provides a country level assessment of competitiveness in achieving sustained economic prosperity (Schwab 2011, http://gcr.weforum.org (http://gcr.weforum.org)). The GCI is a weighted index based on 12 pillars of economic competitiveness: institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labor market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation. The GCI can in theory span from 1 to 7, based on this range, we rescaled the scores to range between 0 and 1. Uninhabited OHI regions are given an NA score.

Units

scaled 0-1

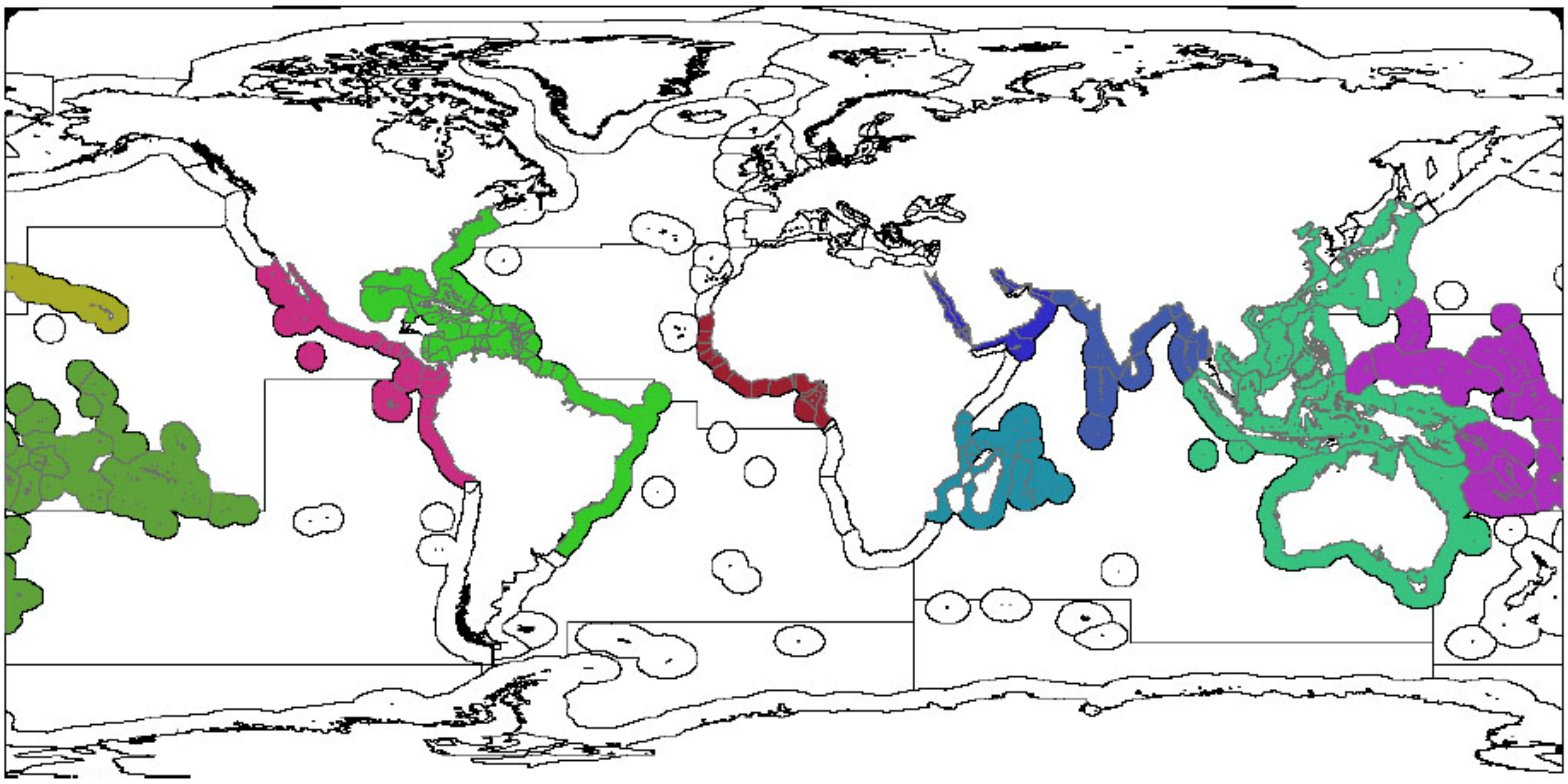
6.27 Habitat condition of coral

hab_coral_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_coral_health.csv)

See **Habitat extent of coral** layer for more information.

Coral condition was calculated using current condition data divided by reference condition. We used condition data from percent live coral cover from 12,634 surveys from 1975-2006 (Bruno and Selig 2007, Schutte et al. 2010). When multiple data points were available for the same site and year, we averaged these data, and also averaged the site data to calculate a per country per year average. However, data were missing for several countries and some countries did not have data for the reference or current year time periods or had only 1-2 surveys. Because coral cover can be highly temporally and spatially dynamic, having only a few surveys that may have been motivated by different reasons (i.e., documenting a pristine or an impacted habitat) can bias results. To calculate condition we used fitted values from a linear trend of all data per country, which was more robust to data poor situations and allowed us to take advantage of periods of intense sampling that did not always include both current and reference years. Then, we created a fitted linear model of all these data points from 1975-2010, provided that 2 or more points are in 1980-1995 and 2 or more points are in 2000-2010. We defined the 'current' condition (health) as the mean of the predicted values for 2008-2010, and the reference condition as the mean of the predicted values for 1985-1987. Where country data were not available, we used an average from adjacent EEZs weighted by habitat area, or a georegional average weighted by habitat area, based on countries within the same ocean basin (Figure 6.1).

Figure 6.1. Georegions to gapfill coral reef data



Units

proportion

6.28 Habitat condition of mangrove

hab_mangrove_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_mangrove_health.csv)

See **Habitat extent of mangrove** layer for more information.

Mangrove condition was defined as the current cover divided by reference cover. FAO mangrove area data was provided on a country basis for 1980, 1990, 2000, and 2005. Current condition is based on 2005 cover, and reference condition is based on the 1980 cover.

Units

proportion

6.29 Habitat condition of saltmarsh

hab_saltmarsh_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_saltmarsh_health.csv)

See **Habitat extent of saltmarsh** layer for more information.

Salt marsh condition was based on trends in salt marsh area for regions where both a current and reference data year were available. An increasing or stable trend was assigned condition = 1.0, and a decreasing trend was assigned condition = 0.5. Data was from multiple sources (Bridgham et al. 2006, Dahl 2011, Ministry for the Environment 2007, JNCC 2004, EEA 2008).

Units

proportion

6.30 Habitat condition of seagrass

hab_seagrass_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seagrass_health.csv)

See **Habitat extent of seagrass** layer for more information.

Seagrass condition was calculated on a per-site basis from Waycott et al. (2009), which provides seagrass habitat extent data for several sites around the world over several years. Reference condition was calculated as the mean of the three oldest years between 1975-1985, or the two earliest years if needed. If data meeting these conditions was not available, we fitted a linear model to all data points, and then used the mean of the predicted values for 1979-1981 as the reference condition. For the current condition we used the mean of the three most recent years after 2000 or the two most recent years. If condition data satisfying these constraints were still not available, we fitted a linear model to all data points, provided that there were at least three data points and then used the mean of the predicted values for 2008-2010 as the current condition and the mean of the predicted values for 1979-1981 as the reference condition. Otherwise, we used neighboring (adjacent) regional averages, weighted by habitat area, or averages weighted by habitat area using seagrass geographical regions as defined by Hemminga and Duarte (2000). We did not project beyond a 15-year timeframe.

Units

proportion

6.31 Habitat condition of seaice

hab_seaice_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seaice_health.csv)

See **Habitat extent of seaice** layer for more information.

Sea-ice condition was calculated using sea-ice concentrations from the USA National Snow and Ice Data Center (Cavalieri et al. 2014; https://nsidc.org/cryosphere/quickfacts/seaice.html (https://nsidc.org/cryosphere/quickfacts/seaice.html)) as the current percent cover of sea-ice (average of 3 years of data) divided by the average historical percent cover, defined as the start of the data (1979) until the year 2000 as recommended by the National Snow & Ice Data Center for both sea-ice edge and sea-ice shoreline habitats.

Units

proportion

6.32 Habitat condition of softbottom

hab_softbottom_health (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_softbottom_health.csv)

See **Habitat extent of softbottom** layer for more information.

Soft bottom subtidal habitat condition was estimated using relative intensity of fishing with demersal destructive gear types. We used global catch data (Watson 2018) that describes the tonnes of harvest for each species and gear type at 0.5 degree raster scale. To estimate the amount of destructive catch, we multiplied each catch record by a value, ranging from 0-1 (1 being the most destructive), based on how destructive the gear type is to soft bottom habitat (trawl and dredge = 1, gillnet and trap = 0.5, “other” = 0.25, and midwater trawl, pole and line, longline, purse seine and seine = 0).

We summed commercial and non-commercial destructive catch for each OHI region and year, and we divided by the area of soft-bottom habitat in the region. The extent of soft-bottom area within a region was defined as shallow subtidal (0-60m) and outer shelf (60-200m) soft bottom habitat. Because these values were extremely skewed, we $ln(X+1)$ transformed them and then rescaled by dividing by the max value across all years/regions.Condition was then calculated as one minus the rescaled catch density in the most recent year and further rescaled to the median condition value across all years. Any value greater than the median was set = 1.0.

Units

proportion

6.33 Habitat condition trend of coral

hab_coral_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_coral_trend.csv)

See **Habitat extent of coral** layer for more information.

Coral trend was calculated using condition data from 1975-2006 (Bruno and Selig 2007, Schutte et al. 2010).

Units

trend

6.34 Habitat condition trend of mangrove

hab_mangrove_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_mangrove_trend.csv)

See **Habitat extent of mangrove** layer for more information.

We used Hamilton and Casey’s (2016) mangrove cover data to estimate the proportional yearly change in mangrove area using a linear regression model of the most recent five years of data (i.e., slope divided by data from the earliest year included in the regression model). The slope was then multiplied by five to get the predicted change in 5 years. The original mangrove data are provided yearly (2000-2012) at 30m raster cell resolution (with the estimated area of mangrove cover in each cell).

Units

trend

6.35 Habitat condition trend of saltmarsh

hab_saltmarsh_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_saltmarsh_trend.csv)

See **Habitat extent of saltmarsh** layer for more information.

General trends in salt marsh area were determined from 1994-2007 using data from multiple sources (Bridgham et al. 2006, Dahl 2011, Ministry for the Environment 2007, JNCC 2004, EEA 2008). For trend estimates, we extracted categorical condition data ('increasing", "stable", "declining" score as 0.5, 0.0, and -0.5, respectively) from these sources on a per country basis when both a current and reference data year were available.

Units

trend

6.36 Habitat condition trend of seagrass

hab_seagrass_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seagrass_trend.csv)

See **Habitat extent of seagrass** layer for more information.

Trend in seagrass condition was determined using two data sources (Waycott et al. 2009, Short et al. 2010). Short et al. (2010) measured percent cover on a per sample, per site, per year basis, whereas Waycott et al. (2009) measured habitat area on a per site, per year basis. We used data from Short if there were at least 3 data points between 2001-2010. If this condition was not met, we calculated trends from Waycott for the most recent 10 years after 1990 or else we used the mean of the trend in the adjacent regions or the regions within the corresponding seagrass geographical regions using the same methods described above for the in status.

Units

trend

6.37 Habitat condition trend of seaice

hab_seaice_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seaice_trend.csv)

See **Habitat extent of seaice** layer for more information.

Trends for sea-ice edge and sea-ice shoreline habitats were calculated using sea-ice concentrations from the USA National Snow and Ice Data Center (Cavalieri et al. 2014; https://nsidc.org/cryosphere/quickfacts/seaice.html (https://nsidc.org/cryosphere/quickfacts/seaice.html)). The average yearly proportional change in extent was estimated using a linear regression model that included the most recent five years of data (e.g., slope estimate was divided by the extent for earliest year included in the regression model), and this value was multiplied by five to get the predicted change in 5 years. Each year of data represents a 3-year average, to smooth yearly variation.

Units

trend

6.38 Habitat condition trend of softbottom

hab_softbottom_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_softbottom_trend.csv)

See **Habitat extent of softbottom** layer for more information.

Trend in soft bottom subtidal condition was estimated using a linear regression model that included the most recent five years of condition data. The proportional change in condition was determined (e.g., slope estimate was divided by the condition value for earliest year included in the regression) and then multiplied by five to get the change predicted in 5 years.

Units

trend

6.39 Habitat extent of coral

hab_coral_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_coral_extent.csv)

Coral data are used to calculate coastal protection goal, habitat subgoal, and exposure variable of the natural products goal.

Coral extent area (km^2) are derived from the 500m resolution dataset developed for Reefs at Risk Revisited (Burke et al. 2011).

Units

km2

6.40 Habitat extent of mangrove

hab_mangrove_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_mangrove_extent.csv)

Mangrove data are used to calculate the coastal protection and carbon storage goals, and the habitat subgoal.

Hamilton and Casey's (2016) yearly (2000-2012) mangrove cover data were used to calculate mangrove extent (km^2). Data were provided at 30m raster cell resolution (with the estimated area of mangrove cover in each cell) which we converted to 500m resolution to facilitate global calculations.

Units

km2

6.41 Habitat extent of rocky reef

hab_rockyreef_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_rockyreef_extent.csv)

Rocky reef data is used to calculate the exposure variable in the natural product goal.

To estimate rocky reef extent area (km^2) we used data from Halpern et al. (2008), which assumes rocky reef habitat exists in all cells within 1 km of shore.

Units

km2

6.42 Habitat extent of saltmarsh

hab_saltmarsh_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_saltmarsh_extent.csv)

Saltmarsh data are used to calculate the coastal proection and carbon storage goals, and the habitat subgoal.

Salt marsh extent area (km^2) comes from multiple sources (Bridgham et al. 2006, Dahl 2000, Ministry for the Environment 2007, JNCC 2004, EEA 2008). In the case of Europe, most data were obtained via the European Environment Agency databases housing information pertaining to the European Union's Habitat Directive.

Severe data gaps exist for several key regions of the world, including the Middle East, South America, and Africa. Extensive salt marshes are believed to exist in the Middle East, bordering the unique salt flat ecosystems known as sabkha, however no numbers concerning extent could be found. Similarly, data on salt marshes in South America were extremely limited, with no estimates on current rates of loss or historical extent from or before the 1970s. The majority of the data included in the model come from North America (United States and Canada), Australia, New Zealand, China, Europe, and the United Kingdom.

Units

km2

6.43 Habitat extent of seagrass

hab_seagrass_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seagrass_extent.csv)

Seagrass data are used to calculate the coastal proection and carbon storage goals, and the habitat subgoal.

Seagrass extent area (km^2) was calculated from vector-based data from the Global Distribution of Seagrasses (UNEP-WCMC 2005).

Units

km2

6.44 Habitat extent of seaice

hab_seaice_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_seaice_extent.csv)

Sea-ice shoreline data are used to calculate the coastal proection goal and sea-ice edge data are used to calculate the habitat subgoal.

Sea-ice extent area (km^2) was calculated using sea-ice concentrations from the USA National Snow and Ice Data Center (Cavalieri et al. 2014; https://nsidc.org/cryosphere/quickfacts/seaice.html (https://nsidc.org/cryosphere/quickfacts/seaice.html)), which are updated yearly. These raster data are 25km in resolution (625km^2 per pixel) in a Stereographic polar projection. Two sea-ice metrics are calculated using these data: sea-ice edge (pixels with 10-50% ice cover) and sea-ice shoreline (shoreline pixels with >15% ice cover). Calculations of area are based on 3-year averages (to smooth yearly variation, e.g., 2009 data is the average of 2007-2009) of the pixels meeting the habitat criteria.

Units

km2

6.45 Habitat extent of softbottom

hab_softbottom_extent (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hab_softbottom_extent.csv)

Softbottom data is one of the variables in the habitat goal and the inverse is a habitat destruction pressure.

Softbottom extent area (km^2) data is from Halpern et al. (2008).

Units

km2

6.46 Habitat presence/absence

element_wts_hab_pres_abs (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/element_wts_hab_pres_abs.csv)

This layer describes the habitats present in each region (based on the habitat extent data) and is called internally by ohicore functions to calculate pressure and resilience values based on the habitats present in each region.

Data is generated in ohi-global/eez/conf/functions.R.

Units

0 or 1

6.47 High bycatch due to artisanal fishing

fp_art_hb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_art_hb.csv)

Pressure

Category: ecological

Subcategory: fishing pressure

This layer describes the relative pressure of high bycatch artisanal fishing practices for each OHI region. The fishery data (Watson 2018) describe catch (tonnes) for each species at the 0.5 degree raster global scale for both non-industrial and industrial fishing. For each raster cell, we summed catch discards from the non-industrial global catch data.

The catch was then divided by the mean net primary productivity (mg C/m^2/day) derived from monthly output from the Vertically Generalized Production Model (VGPM, http://www.science.oregonstate.edu/ocean.productivity/ (http://www.science.oregonstate.edu/ocean.productivity/), 0.5 degree global raster data). Standardizing catch by primary productivity controls for the fact that similar amounts of catch impart different pressures depending on the productivity in the region.

The layer was rescaled from 0 to 1 using the 99.99th quantile of the entire data layer across all years of data.

To summarize at the OHI region scale, the mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.48 High bycatch due to commercial fishing

fp_com_hb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_com_hb.csv)

Pressure

Category: ecological

Subcategory: fishing pressure

This layer describes the relative pressure of high bycatch commercial fishing practices for each OHI region. The fishery data (Watson 2018) describe catch (tonnes) for each species and gear type at the 0.5 degree raster global scale for both non-industrial and industrial fishing. For each raster cell, we summed catch discards from the industrial global catch data.

The catch was then divided by the mean net primary productivity (mg C/m^2/day) derived from monthly output from the Vertically Generalized Production Model (VGPM, http://www.science.oregonstate.edu/ocean.productivity/ (http://www.science.oregonstate.edu/ocean.productivity/), 0.5 degree global raster data). Standardizing catch by primary productivity controls for the fact that similar amounts of catch impart different pressures depending on the productivity in the region.

The layer was rescaled from 0 to 1 using the 99.99th quantile of the entire data layer across all years of data.

To summarize at the OHI region scale, the mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.49 Inland 1km area

rgn_area_inland1km (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/rgn_area_inland1km.csv)

See **Region areas based on EEZ boundaries** layer for more information.

Area (km^2) located from each region's land-sea interface to 1 km inland.

For coastal land areas, we extracted hi-resolution country boundary data from ESRI (2010), and rasterized it with a resolution to match our land-sea interface model. We grew this raster by 50 pixels to bridge gaps between the ESRI data and our land-sea model. Area values do not include inland lakes or EEZs.

Units

km2

6.50 Inland coastal population

mar_coastalpopn_inland25mi (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/mar_coastalpopn_inland25mi.csv)

Coastal population was determined for each region using Gridded Population of the World (GPW) Population Count Grid Future Estimates from the Center for International Earth Science Information Network - CIESIN - Columbia University (CIESIN, 2016 (http://dx.doi.org/10.7927/H4X63JVC)). Global data were provided at 30 arc second resolution for five year intervals: eg., 2005, 2010, 2015, 2020. Intervening years were temporally interpolated, as: d2013 = 0.4 * d2010 + 0.6 * d2015. The total coastal population count data was calculated for each region by extracting the relevant cell data using a 25-mile inland coastal zone shapefile.

Units

count

6.51 Inland coastal protected areas

lsp_prot_area_inland1km (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/lsp_prot_area_inland1km.csv)

This includes protected areas 1km inland, but otherwise follows the methods described in **Offshore coastal protected areas**.

Units

km2

6.52 Intertidal habitat destruction

hd_intertidal (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_intertidal.csv)

Pressure

Category: ecological

Subcategory: habitat destruction

See **Inland coastal population** for more information about the population data.

Coastal population data was converted to average coastal density by dividing by the total 25 mile inland area. We then rescaled the data to have values between 0-1, by logging the density data and then dividing by the ln (maximum density) across all regions and years.

Units

scaled 0-1

6.53 IUCN extinction risk

ico_spp_iucn_status (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/ico_spp_iucn_status.csv)

This data layer provides the risk category and the year the species was assessed from the IUCN Red List of Threatened Species (http://www.iucnredlist.org/ (http://www.iucnredlist.org/)) for the iconic species in each region. Regionally specific IUCN risk category data for *subpopulations* are included where available. Trend calculations are based on the change in each species' IUCN risk category over time, based upon past and current IUCN assessments.

OHI defines iconic species as those relevant to local cultural identity through the species' relationship to traditional activities such as fishing, hunting, commerce or involvement in local ethnic or religious practices; and species with locally-recognized aesthetic value (e.g., touristic attractions/common artistic subjects such as whales). Habitat forming species are excluded in this definition of iconic species. The OHI global iconic species list combines three species lists from WWF Global: global priorities, regional and local priorities, and flagship species. The criteria for including species on the WWF lists are consistent with the OHI's definition of iconic species.

Once the species lists were obtained, each species was assigned to a region based on native range countries from the IUCN Red List.

Most of the iconic species are not region specific, and the global list is applied across all regions. However, some countries have developed national priority and flagship species lists in conjunction with WWF. These region-specific iconic species lists supplement the global list for those specific countries only. In addition, as countries and regions conduct OHI regional assessments (http://ohi-science.org/projects/ (http://ohi-science.org/projects/)), we will use the iconic species list developed by those countries/regions to supplement our global model. For example, iconic species identified for the Baltic Health Index regional assessment have been included for all countries bordering the Baltic Sea.

Table 6.6. Iconic species resources

Iconic List	Source
Priority Species	http://wwf.panda.org/what_we_do/endangered_species/ (http://wwf.panda.org/what_we_do/endangered_species/)
Flagship Species	http://wwf.panda.org/what_we_do/endangered_species/ (http://wwf.panda.org/what_we_do/endangered_species/)
Australia's Flagship Species	http://www.wwf.org.au/our_work/saving_the_natural_world/wildlife_and_habitats/australian_priority_species/ (http://www.wwf.org.au/our_work/saving_the_natural_world/wildlife_and_habitats/australian_priority_species/)
Pakistan's Priority Species	http://www.wwfpak.org/species/priority_species.php (http://www.wwfpak.org/species/priority_species.php)
India's Priority Species	http://www.wwfindia.org/about_wwf/priority_species/ (http://www.wwfindia.org/about_wwf/priority_species/)
Madagascar's Flagship Species	http://www.wwf.mg/ourwork/cssp/species_report/wwf_madagascar_s_flagship_species/ (http://www.wwf.mg/ourwork/cssp/species_report/wwf_madagascar_s_flagship_species/)
Malaysia's Flagship Species	http://www.wwf.org.my/about_wwf/what_we_do/species_main/ (http://www.wwf.org.my/about_wwf/what_we_do/species_main/)
Portugal's Flagship Species	http://www.wwf.pt/o_nosso_planeta/especies/top_5_das_especies_de_portugal___as_cinco_especies_mais_ameacadas_e_ (http://www.wwf.pt/o_nosso_planeta/especies/top_5_das_especies_de_portugal___as_cinco_especies_mais_ameacadas_e_) emblematicas_de_portugal/
Peru's Priority Species	http://peru.panda.org/nuestro_trabajo/iniciativas_globales/ (http://peru.panda.org/nuestro_trabajo/iniciativas_globales/)

Units

IUCN risk category

6.54 Livelihood status scores

liv_status (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/liv_status.csv)

This layer provides calculated status values for the livelihoods subgoal. Livelihoods is calculated using job and wage data from marine sectors.

Note: These data are no longer supported. Consequently, this layer was last updated in 2013, and this goal will no longer be updated with these data.

Livelihoods status is generally calculated as: (cur_base_value / ref_base_value) / (cur_adj_value / ref_adj_value)

Where, cur_base_value is the most recent value (i.e., jobs or wages) for each sector/region, and ref_base_value is the value for the earliest year of data for each sector/region. These values are adjusted to control for larger trends within the region. For example, jobs data for the livelihoods subgoal was adjusted by dividing by the percent employment of the corresponding year. For wage data, the adjustment was done a bit differently by multiplying wages by GDPpcPPP for each year/region to make wages comparable.

6.54.1 Jobs

Jobs includes yearly data for commercial fishing, mariculture, marine mammal watching, marine renewable energy, and, tourism. The data sources and methods for each sector are described below.

Percent employment during the current status year for each sector/region is calculated as (1 - percent unemployment)*total labor force (World Bank). Jobs data for the livelihoods subgoal were adjusted by dividing by the percent employment in the corresponding year.

6.54.1.1 Commercial fishing

Data are from the United Nations Food and Agriculture Organization (FAO) Fisheries and Aquaculture Department which provides a Global Number of Fishers dataset (http://www.fao.org/fishery/statistics/global-fishers/en (http://www.fao.org/fishery/statistics/global-fishers/en.)). The data include yearly total numbers of employees in commercial fishing, subsistence fishing, and aquaculture (land- and ocean-based combined) in more than 160 countries. The dataset includes the following occupational categories: aquatic-life cultivation, inland waters fishing, marine coastal waters fishing, marine deepsea waters fishing, subsistence and unspecified. We omitted jobs with an unspecified category to avoid overestimating employment for marine fishing or aquaculture. We omitted jobs in the subsistence category since subsistence opportunities are captured by the artisanal fishing opportunity goal and in the aquatic-life cultivation category since that represents a distinct sector (see mariculture below). For commercial fishing, we eliminated inland waters fishing and summed marine coastal waters and marine deep-sea waters fishing for each country in each year. Data are reported separately for men and women, but we summed these numbers. Employment is disaggregated into full-time, parttime, occasional, and unspecified statuses. These categories are defined as full time workers having > 90% of their time or livelihood from fishing/aquaculture, part time workers are between 30-90% time (or 30-90% of their livelihood) and occasional workers are < 30% time. Unspecified status workers could fall anywhere from 0-100% time. Taking the midpoints of those ranges, we assume that 1 part time worker = 0.6 full time workers, 1 occasional worker = 0.15 full time workers, and 1 unspecified worker = 0.5 full time workers, which we used as a weighting scheme for determining total numbers of jobs. The dataset has significant gaps, but it provides the most comprehensive source of global data on commercial fishing and aquaculture employment.

6.54.1.2 Mariculture

We used the FAO Global Number of Fishers dataset (see commercial fishing above for full description) to estimate jobs for mariculture. For this sector, we used data in the aquatic-life cultivation category. Again, employment is disaggregated into full-time, part-time, occasional, and unspecified statuses and we implement a weighting scheme where full time = 1 job, part-time = 0.6, occasional = 0.15, and unspecified = 0.5. Aquatic-life cultivation includes marine, brackish and freshwater aquaculture. In order to estimate the proportion of total aquaculture jobs that can be attributed to marine and brackish aquaculture, we used country-specific proportions of marine and brackish aquaculture revenues (compared to total revenues) calculated from FAO aquaculture production data, assuming that numbers of jobs approximately scale with production in terms of revenue. For country-years with no data for the proportion of marine/brackish production because of gaps in the FAO production data, we used the proportion from the most recent year for which data were available. For countries without proportion estimates from any years, we used the average proportion from the country's geographic region (e.g., Caribbean, Polynesia, Eastern Asia), with the exception of American Samoa, for which we used the proportion value from Guam.

6.54.1.3 Marine mammal watching

The International Fund for Animal Welfare's (IFAW) Whale Division provides time series data on whale watching in more than 115 coastal countries (O'Connor et al 2009). This dataset may be an imperfect representation of all marine mammal watching due to its focus on whales, although it does include data for other types of marine mammal watching (e.g., dolphins). However, to our knowledge, it is the most complete dataset pertaining to the global marine mammal watching industry. We obtained regional averages of the number of whale watchers per employee, as well as the number of whale watchers in each country. Using this information, we estimated the number of whale watching jobs in each country by dividing the country's total number of whale watchers by the average number of whale watchers per employee for that country's region (e.g., Africa & Middle East, Europe, North America). It is important to note that data are not annual, but there are at least four years of data for each country. When IFAW reported "minimal" numbers of whale watchers, we converted this description to a 0 for lack of additional information. Because some of the whale watching in O'Connor et al. focused on freshwater cetacean viewing, we categorized the target species listed for each country as freshwater or marine. For countries with both marine and freshwater species, we categorized the whale watching in those countries as either 50% or 90% marine, based on the number of marine versus freshwater target species and information provided in the report narrative. For Colombia and Indonesia, more detailed information in the report narrative allowed for a more precise determination of the percentage of marine-based whale watching. We applied these marine proportions to data on the number of whale watchers before converting these estimates into employment estimates.

6.54.1.4 Marine renewable energy

The number of marine renewable energy jobs was determined for the two countries, France and Canada, which produce significant enough amounts of tidal energy to register with the UN Energy Statistics Database http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aEO (http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aEO). For the La Rance plant in France, employment information was obtained from a recent press statement (EDF 2011); we assumed employment stayed constant over the time period for which we had production data for this plant, given relatively consistent or even growing production. For the Annopolis Royal plant in Canada, we received yearly employment information from the plant (Ruth Thorbourne, personal communication, Aug 9 2011).

Marine renewable energy includes five major technologies: tidal barrages, marine currents, waves, ocean thermal converters and salinity gradients. However, we only include data for the largest tidal barrage plants, as these data are available.

6.54.1.5 Tourism

The World Travel & Tourism Council (WTTC) provides data on travel and tourism's total contribution to employment for 180 countries (http://www.wttc.org/eng/Tourism_Research/Economic_Data_Search_Tool/ (http://www.wttc.org/eng/Tourism_Research/Economic_Data_Search_Tool/)). Although other global data sources on tourism are available (i.e., United Nations World Tourism Organization, UNTWO), the WTTC database was chosen because it offers yearly time series data that span through the current year, it includes nearly complete coverage of all nations, and it disaggregates direct and total (direct plus indirect) employment impacts of tourism. WTTC provides projected data, however, we do not use these values. We used total employment data to avoid the use of literature derived multiplier effects. The WTTC shares a significant drawback with UNTWO data, in that data on coastal/marine and inland tourism are lumped. Therefore, a country-specific coefficient must be applied to estimate the jobs provided by coastal/marine tourism alone. We adjusted national tourism data by the proportion of a country's population that lives within a 25 mile inland coastal zone.

6.54.2 Wages

Wages were multiplied by GDPpcPPP for each country/year to make values comparable.

We used the Occupational Wages around the World (OWW) database produced by Remco H. Oostendorp and Richard B. Freeman in 2005 (http://www.nber.org/oww/ (http://www.nber.org/oww/)). These data were drawn from the International Labour Organization and subjected to a standardization process (for more information, see http://www.nber.org/oww/Technical _document_1983-2003_standardizationv3.pdf (http://www.nber.org/oww/Technical%20_document_1983-2003_standardizationv3.pdf)). The database provides several different calibrations, and we use the "x3wl calibration", described as a "country-specific and uniform calibration with lexicographic weighting," and recommended as being the preferred calibration in most cases. Although significant gaps exist in this database, it contains country-specific information on average wages in many industries for more than 150 countries from 1983-2003. Data represent average monthly wages of a male worker. Wage data were divided by the inflation conversion factor for 2010 so that wage data across years would be comparable (http://oregonstate.edu/cla/polisci/sahr/sahr (http://oregonstate.edu/cla/polisci/sahr/sahr)), and then multiplied by the purchasing power parity-adjusted per capita gdp (ppppcgdp, WorldBank). The adjusted wage data were then multiplied by 12 to get annual wages. We used the industry and occupation classifications reported in the OWW to estimate wages for marine-related sectors.

Table 6.10. Occupation classification for wage data sectors

Sector	Occupation classifications
Commercial fishing	Industry: deep sea & coastal fishing; Occupations: deep sea fisher; inshore (coastal) maritime fisherman
Ports & harbors	Industry: supporting services to maritime transport; Occupation: dock worker
Ship & boat building	Industry: shipbuilding and repairing; Occupation: ship plater
Tourism	Industry: restaurants and hotels; Occupations: hotel receptionist; cook; waiter; room attendant or chambermaid. These data are not specific to coastal/marine tourism jobs, and thus we assumed that wages in these jobs are equal in coastal and non-coastal areas
Transportation & shipping	Industry: maritime transport; Occupations: ship's chief engineer; ship's passenger stewards; able seaman

Units

status 0-100

6.55 Livelihood trend scores

liv_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/liv_trend.csv)

See **Livelihood status scores** layer for more information about data and methods.

This layer provides calculated trend values for the livelihoods subgoal. Livelihoods is calculated using job and wage data from marine sectors.

Note: These data are no longer supported. Consequently, this layer was last updated in 2013, and this goal will no longer be updated with these data.

Units

trend -1 to 1

6.56 Low bycatch due to artisanal fishing

fp_art_lb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_art_lb.csv)

Pressure

Category: ecological

Subcategory: fishing pressure

This layer describes the relative pressure of low bycatch artisanal fishing practices for each OHI region. The fishery data (Watson 2018) describe catch (tonnes) for each species at the 0.5 degree raster global scale for both non-industrial and industrial fishing. For each raster cell, we summed catch (which consisted of reported landings as well as illegal, unreported and regulated catch) from the non-industrial global catch data.

The catch was then divided by the mean net primary productivity (mg C/m^2/day) derived from monthly output from the Vertically Generalized Production Model (VGPM, http://www.science.oregonstate.edu/ocean.productivity/ (http://www.science.oregonstate.edu/ocean.productivity/), 0.5 degree global raster data). Standardizing catch by primary productivity controls for the fact that similar amounts of catch impart different pressures depending on the productivity in the region.

The layer was rescaled from 0 to 1 using the 99.99th quantile of the entire data layer across all years of data.

To summarize at the OHI region scale, the mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.57 Low bycatch due to commercial fishing

fp_com_lb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_com_lb.csv)

Pressure

Category: ecological

Subcategory: fishing pressure

This layer describes the relative pressure of low bycatch commercial fishing practices for each OHI region. The fishery data (Watson 2018) describe catch (tonnes) for each species and gear type at the 0.5 degree raster global scale for both non-industrial and industrial fishing. For each raster cell, we summed catch (which consisted of reported landings as well as illegal, unreported and regulated catch) from the industrial global catch data.

The catch was then divided by the mean net primary productivity (mg C/m^2/day) derived from monthly output from the Vertically Generalized Production Model (VGPM, http://www.science.oregonstate.edu/ocean.productivity/ (http://www.science.oregonstate.edu/ocean.productivity/), 0.5 degree global raster data). Standardizing catch by primary productivity controls for the fact that similar amounts of catch impart different pressures depending on the productivity in the region.

The layer was rescaled from 0 to 1 using the 99.99th quantile of the entire data layer across all years of data.

To summarize at the OHI region scale, the mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.58 Management of habitat to protect fisheries biodiversity

fp_habitat (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_habitat.csv)

Resilience

Category: ecological/regulatory

Subcategory: fishing

Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). Each question was weighted equally within each category and responses were averaged to give a score between 0 and 1 for all responding countries. The survey uses a 0 to 3 scale for questions 79 and 81, and a 0 to 2 scale for question 80, which we rescale linearly to 0 to 1.

All countries were given credit within each of the 4 resilience measures for simply being a member of the CBD (0.5), the other 0.5 of the resilience score came from each country's response to the specific questions within each resilience measure. In cases where the "European Union" answered yes or was a signatory, all EU25 countries were given that answer if they did not provide one themselves.

The CBD has 193 members and 153 members responded to the Third National Survey (2005). We had data for 147 regions, and used geographical means, weighted by country area, for the remaining regions.

Questions: 153 (a,b,c,e,g) and 158 (a,b,c,f,g,h)

153. Do your country's strategies and action plans include the following?

   a. Developing new marine and coastal protected areas
   b. Improving the management of existing marine and coastal protected areas
   c. Building capacity within the country for management of marine and coastal resources, including through educational programmes and targeted research initiatives
   d. Protection of areas important for reproduction, such as spawning and nursery areas
   e. Controlling excessive fishing and destructive fishing practices

158. Which of the following statements can best describe the current status of marine and coastal protected areas in your country?

   a. Marine and coastal protected areas have been declared and gazetted
   b. Management plans for these marine and coastal protected areas have been developed with involvement of all stakeholders
   c. Effective management with enforcement and monitoring has been put in place
   d. The national system of marine and coastal protected areas includes areas managed for purpose of sustainable use, which may allow extractive activities
   e. The national system of marine and coastal protected areas includes areas which exclude extractive uses
   f. The national system of marine and coastal protected areas is surrounded by sustainable management practices over the wider marine and coastal environment.

Units

scaled 0-1

6.59 Management of habitat to protect habitat biodiversity

hd_habitat (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_habitat.csv)

Resilience

Category: ecological/regulatory

Subcategory: habitat

See **Management of habitat to protect fisheries biodiversity** layer for data and methods.

Units

scaled 0-1

6.60 Management of mariculture to preserve biodiversity

g_mariculture (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/g_mariculture.csv)

Resilience

Category: ecological/regulatory

Subcategory: goal

Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). Each question was weighted equally within each category and responses were averaged to give a score between 0 and 1 for all responding countries. The survey uses a 0 to 3 scale for questions 79 and 81, and a 0 to 2 scale for question 80, which we rescale linearly to 0 to 1.

All countries were given credit within each of the 4 resilience measures for simply being a member of the CBD (0.5), the other 0.5 of the resilience score came from each country's response to the specific questions within each resilience measure. In cases where the "European Union" answered yes or was a signatory, all EU25 countries were given that answer if they did not provide one themselves.

The CBD has 193 members and 153 members responded to the Third National Survey (2005). We had data for 147 regions, and used geographical means, weighted by country area, for the remaining regions.

Questions: 158 (d) and 159 (a-l)

158. Which of the following statements can best describe the current status of marine and coastal protected areas in your country?

   d. A national system or network of marine and coastal protected areas is under development

159. Is your country applying the following techniques aimed at minimizing adverse impacts of mariculture on marine and coastal biodiversity?

   a. Application of environmental impact assessments for mariculture developments
   b. Development and application of effective site selection methods in the framework of integrated marine and coastal area management
   c. development of effective methods for effluent and waste control
   d. Development of appropriate genetic resource management plans at the hatchery level
   e. Development of controlled hatchery and genetically sound reproduction methods in order to avoid seed collection from nature.
   f. If seed collection from nature cannot be avoided, development of environmentally sound practices for spat collecting operations, including use of selective fishing gear to avoid by-catch
   g. Use of native species and subspecies in mariculture
   h. Implementation of effective measures to prevent the inadvertent release of mariculture species and fertile polypoids.
   i. Use of proper methods of breeding and proper places of releasing in order to protect genetic diversity
   j. Minimizing the use of antibiotics through better husbandry techniques
   k. Use of selective methods in commercial fishing to avoid or minimize bycatch
   l. Considering traditional knowledge, where applicable, as a source to develop sustainable mariculture techniques

Units

scaled 0-1

6.61 Management of nonindigenous species

sp_alien_species (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/sp_alien_species.csv)

Resilience

Category: ecological/regulatory

Subcategory: nonindigenous species

Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). Each question was weighted equally within each category and responses were averaged to give a score between 0 and 1 for all responding countries. The survey uses a 0 to 3 scale for questions 79 and 81, and a 0 to 2 scale for question 80, which we rescale linearly to 0 to 1.

All countries were given credit within each of the 4 resilience measures for simply being a member of the CBD (0.5), the other 0.5 of the resilience score came from each country's response to the specific questions within each resilience measure. In cases where the "European Union" answered yes or was a signatory, all EU25 countries were given that answer if they did not provide one themselves.

The CBD has 193 members and 153 members responded to the Third National Survey (2005). We had data for 147 regions, and used geographical means, weighted by country area, for the remaining regions.

Questions: 160 (b-e)

160. Has your country put in place mechanisms to control pathways of introduction of alien species in the marine and coastal environment? Please check all that apply and elaborate on types of measures in the space below.

   a. No
   b. Mechanisms to control potential invasions from ballast water have been put in place

c. Mechanisms to control potential invasions from hull fouling have been put in place (please provide details below)
d. Mechanisms to control potential invasions from aquaculture have been put in place (please provide details below)
e. Mechanisms to control potential invasions from accidental releases, such as aquarium releases, have been put in place (please provide details below)

Units

scaled 0-1

6.62 Management of tourism to preserve biodiversity

g_tourism (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/g_tourism.csv)

Resilience

Category: ecological/regulatory

Subcategory: goal

Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). Each question was weighted equally within each category and responses were averaged to give a score between 0 and 1 for all responding countries. The survey uses a 0 to 3 scale for questions 79 and 81, and a 0 to 2 scale for question 80, which we rescale linearly to 0 to 1.

All countries were given credit within each of the 4 resilience measures for simply being a member of the CBD (0.5), the other 0.5 of the resilience score came from each country's response to the specific questions within each resilience measure. In cases where the "European Union" answered yes or was a signatory, all EU25 countries were given that answer if they did not provide one themselves.

The CBD has 193 members and 153 members responded to the Third National Survey (2005). We had data for 147 regions, and used geographical means, weighted by country area, for the remaining regions.

Questions: 79, 80, 82

79. Has your country established mechanisms to assess, monitor and measure the impact of tourism on biodiversity?

a. No
b. No, but mechanisms are under development
c. Yes, mechanisms are in place (please specify below)
d. Yes, existing mechanisms are under review

80. Has your country provided educational and training programmes to the tourism operators so as to increase their awareness of the impacts of tourism on biodiversity and upgrade the technical capacity at the local level to minimize the impacts?

a. No
b. No, but programmes are under development
c. Yes, programmes are in place (please describe below)

82. Does your country provide indigenous and local communities with capacity-building and financial resources to support their participation in tourism policy-making, development planning, product development and management?

a. No
b. No, but relevant programmes are being considered
c. Yes, some programmes are in place
d. Yes, comprehensive programmes are in place

Units

scaled 0-1

6.63 Management of waters to preserve biodiversity

po_water (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_water.csv)

Resilience

Category: ecological/regulatory

Subcategory: water

Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). Each question was weighted equally within each category and responses were averaged to give a score between 0 and 1 for all responding countries. The survey uses a 0 to 3 scale for questions 79 and 81, and a 0 to 2 scale for question 80, which we rescale linearly to 0 to 1.

All countries were given credit within each of the 4 resilience measures for simply being a member of the CBD (0.5), the other 0.5 of the resilience score came from each country's response to the specific questions within each resilience measure. In cases where the "European Union" answered yes or was a signatory, all EU25 countries were given that answer if they did not provide one themselves.

The CBD has 193 members and 153 members responded to the Third National Survey (2005). We had data for 147 regions, and used geographical means, weighted by country area, for the remaining regions.

Questions: 153 (d,f)

153. Do your country's strategies and action plans include the following?

d. Instituting improved integrated marine and coastal area management (including catchments management) in order to reduce sediment and nutrient loads into the marine environment
e. Improving sewage and other waste treatment

Units

scaled 0-1

6.64 Mariculture harvest

mar_harvest_tonnes (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/mar_harvest_tonnes.csv)

Mariculture production from the FAO Global Aquaculture Production Quantity dataset. Only production classified in the "Marine" and "Brackishwater" environments was included in the analysis (all "Freshwater" production was excluded). Non-edible seaweeds were excluded because they are included in the natural products goal. All species produced within a country were summed to give a single production value for each country in each year that production took place. For the three EEZs that fall within the China region (China, Macau, and Hong Kong), we combined the values by summing across these EEZs.

Units

tonnes

6.65 Mariculture Sustainability Index

g_msi_gov (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/g_msi_gov.csv)

Resilience

Category: ecological/regulatory

Subcategory: goal

See **Mariculture sustainability score** for more information about these data.

Two mariculture practice criteria from the Marine Sustainability Index (Trujillo 2008) contributed to the resilience of mariculture (traceability and code of practice). These are the only 2 social criteria assessed in the MSI that have the potential to positively affect the long term resilience of a mariculture system.

The MSI reports data for 359 country-species combinations (with 60 countries and 86 species represented) for each assessment criterion. Scores for each assessment criterion were aggregated and averaged. All country average scores were then rescaled from 0 to 1 using the maximum possible raw MSI score of 10 and minimum of 1, and then weighted equally to come up with a composite resilience.

Unlike the mariculture sustainability data (**Mariculture sustainability score**), gapfilling was not performed when country specific data were not available for the two resilience measures because these measures are social in nature and reliant on the specific decisions made by each country rather than on the species cultured. As such, it was decided that crosscountry species averages were not appropriate to use in the gapfilling process for resilience.

Table 6.7. Mariculture Sustainability Index criteria

Criteria	Description of practice and score scheme
Code of practice usage	Certification, up to date set of standards and principles, i.e., FAO Code of Conduct (FAO 1995, 1999), or Eco-labelling are scored high, while no certification or similar scheme scores low (1)
Traceability	Food safety related to a specific geographical origin, slaughtering or processing facility, and batch of fish can be identified scores high (8-9). If the original and preparation of feed used in the farmed sector is included then scores high (10).

Units

scaled 0-1

6.66 Mariculture sustainability score

mar_sustainability_score (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/mar_sustainability_score.csv)

Three mariculture practice criteria from the Marine Sustainability Index (Trujillo 2008) contributed to the sustainability of mariculture (fishmeal use, waste treatment, and seed and larvae origin criteria). These criteria represent the internal mariculture practices with the potential to affect the long term sustainability of the mariculture system. The MSI reports data for 359 country-species combinations (with 60 countries and 86 species represented) for each assessment criterion. Scores for each assessment criterion were aggregated and averaged based on the proportion of the landings that each assessed species contributed to the overall catch in each country in the current year. All country average scores were then rescaled from 0 to 1 using the maximum possible raw MSI score of 10 and minimum of 1, and then weighted equally to calculate a composite resilience. Because the Index comprises species-specific sustainability values that are combined as a catch-weighted average, when the list of species harvested changes, the sustainability index used in the mariculture sub-goal model also changes due to shifts in the relative composition of harvested species.

Species/country combinations that were not assessed by the MSI were gapfilled using average data from similar taxonomic groupings from other countries (ideally we used the same species, but used more general taxonomic groupings when necessary).

Table 6.8. Mariculture sustainability criteria

Criteria	Description of practice and score scheme
Fishmeal use	Fish protein and oil inclusion in the diet at any stage of development must be considered; herbivore species will score 10, and carnivorous (piscivorous) organisms will score closer to 1, depending on the level of feed supplied.
Waste treatment	Water exchange, output destinations, recycling and filtering of open water discharge or closed system reuse systems. Systems that are closed score high (10), while open systems

	without waste treatments score low (1)
Seed and larvae origin	Hatcheries are major providers of larvae, fry and seeds. Broodstock origin and strain will also affect the score. Wild seed collection and its importance contribute to a low score due to bycatch and other effects on non-target species.

Units

scaled 0-1

6.67 Marine plastics

po_trash (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_trash.csv)

Pressure

Category: ecological

Subcategory: pollution

Marine plastic pollution is modeled using data on the global distribution of floating marine plastics at 0.2 degree resolution (Erikson et al. 2014). Specifically, weight of floating plastics (g/km^2) across four different size classes were aggregated to represent total weight of plastic debris per km^2. These data were log transformed and rescaled from 0 to 1 using the 99.99th quantile as the reference point.

Units

scaled 0-1

6.68 Measure of coastal ecological integrity

species_diversity_3nm (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/species_diversity_3nm.csv)

Resilience

Category: ecological/ecosystem

See Species goal for calculations.

This value reflects the average condition of species (based on risk status from the IUCN Red List of Threatened Species, http://www.iucnredlist.org/ (http://www.iucnredlist.org/)) located within 3 nm offshore of each region based on species range maps from IUCN (shapefiles, used preferentially) and Aquamaps (http://www.aquamaps.org/ (http://www.aquamaps.org/), half degree resolution rasters).

Units

scaled 0-1

6.69 Measure of ecological integrity

species_diversity_eez (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/species_diversity_eez.csv)

Resilience

Category: ecological/ecosystem

See Species goal for calculations.

This value reflects the average condition of species (based on risk status from the IUCN Red List of Threatened Species, http://www.iucnredlist.org/ (http://www.iucnredlist.org/)) located within the eez of each region based on species range maps from IUCN (shapefiles, used preferentially) and Aquamaps (http://www.aquamaps.org/ (http://www.aquamaps.org/), half degree resolution rasters).

Units

scaled 0-1

6.70 Natural product harvest

np_harvest_tonnes (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/np_harvest_tonnes.csv)

The total tonnes of six natural product commodities (corals, ornamental fish, shells, fish oil, inedible seaweeds and plants, and sponges) were determined for each region using export data from the FAO Global Commodities database. For each group the sum of the subcategories was calculated. For ornamental fish we excluded the subcategory 'Fish for culture including ova, fingerlings, etc.' because it is not specific to ornamental fish, and the subcategory 'Ornamental freshwater fish' because it is not from marine systems. Corals and shells are reported together in nine subcategories; we used the subcategories most closely tied to each, leading to the sum of two subcategories for corals and seven subcategories for shells (one subcategory was used for both). We did not use one subcategory – 'Powder and waste of shells' – as it likely a byproduct of the other subcategories rather than a primary target (and it comprises a very small amount of the total anyway).

If a country was missing tonnes or dollar values (but had one of the values), the missing data were estimated. FAO provides yearly data for the tonnes and dollar value generated for each natural product, however, countries often provide only one of these variables (and the data provided varies across years). To estimate these missing data, we used country-specific linear models to predict tonnes based on the dollar value of a product (or, vice versa). For the countries that did not have enough data to develop an adequate model, our models included the data for all the countries within a UN geopolitical region. When there wasn't enough data at the geopolitical region scale, we used all the global data to predict missing values.

Table 6.9. FAO categories included in each natural product commodity

commodity	subcategory
corals	Coral and the like
fish oil	Alaska pollack oil, nei, Anchoveta oil, Capelin oil, Clupeoid oils, nei, Cod liver oil, Fish body oils, nei, Fish liver oils, nei, Gadoid liver oils, nei, Hake liver oil, Halibuts, liver oils, Herring oil, Jack mackerel oil, Menhaden oil, Pilchard oil, Redfish oil, Sardine oil, Shark liver oil, Shark oil, Squid oil, Pelagic fish oils, nei, Gadiformes, oil, nei, Demersal fish oils, nei, Alaska pollock, oil, nei
ornamentals	Ornamental saltwater fish, Ornamental fish nei
seaweeds	Agar agar in powder, Agar agar in strips, Agar agar nei, Carrageen (Chondrus crispus), Green laver, Hizikia fusiforme (brown algae), Kelp, Kelp meal, Laver, dry, Laver, nei, Other brown algae (laminaria, eisenia/ecklonia), Other edible seaweeds, Other inedible seaweeds, Seaweeds and other algae, unfit for human consumption, nei, Seaweeds and other algae, fit for human consumption, nei, Other red algae, Other seaweeds and aquatic plants and products thereof, Undaria pinnafitida (brown algae)
shells	Abalone shells, Miscellaneous corals and shells, Mother of pearl shells, Oyster shells, Sea snail shells, Shells nei, Trochus shells
sponges	Natural sponges nei, Natural sponges other than raw, Natural sponges raw

Units

tonnes

6.71 Nonindigenous species

sp_alien (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/sp_alien.csv)

Pressure

Category: ecological

Subcategory: nonindigenous species

These data (Molnar et al. 2008) report the number and type of alien species in each marine ecoregion (Spalding et al. 2007), with species types categorized as invasive and harmful invasive species. For our purposes, total count of all invasive species was used. We intersected the ecoregion data with our reporting units to determine the proportion of each ecoregion that falls within each reporting unit and then assigned this percentage of invasive species from the ecoregion to the reporting unit. The sum of all invasive species within each reporting unit was then rescaled to the maximum global value. Predicting the full potential impact of alien species depends in large part on having high-resolution spatial information on where they exist, how far they have spread and exactly which components of the food web they affect. The data from Molnar et al. approximate these impacts but at ecoregional scales. In addition, the impacts of alien species will vary depending on the goal under consideration. This implies that harmful effects would need to be assessed separately for each goal. Such an endeavor may be possible when applying this framework to a smaller case-study where this type of information can be acquired.

Units

scaled 0-1

6.72 Nutrient pollution

po_nutrients (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_nutrients.csv)

Pressure

Category: ecological

Subcategory: pollution

Data were calculated using modeled plumes of land-based nitrogen pollution that provide intensity of pollution at ~1km resolution (Halpern et al. 2008).

Nitrogen pollution was estimated from FAO data on annual country-level fertilizer use (http://faostat3.fao.org/faostat-gateway/go/to/browse/R/*/E (http://faostat3.fao.org/faostat-gateway/go/to/browse/R/*/E)), with missing values estimated by regression between fertilizer and pesticides when possible, and when not possible with agricultural GDP as a proxy. Data were summed across all fertilizer compounds and reported in metric tons. Upon inspection the data included multiple 0 values that are most likely data gaps in the time-series, so they were treated as such and replaced with NA. In addition, regions with only 1 data point and regions where the most recent data point was prior to 2005 were excluded. Uninhabited countries were assumed to have no fertilizer use and thus excluded.

These country-level pollution values were then dasymetrically distributed over a country's landscape using global landcover data from 2009, derived from the MODIS satellite at ~500m resolution. These values were then aggregated by ~140,000 global basins, and diffusive plumes were modeled from each basin's pourpoint. The final non-zero plumes (about ~76,000) were aggregated into ~1km Mollweide (wgs84) projection rasters to produce a single plume-aggregated pollution raster.

These raw values were then $ln(X + 1)$ transformed and normalized to 0-1 by dividing by the 99.99th quantile of raster values across all years. The zonal mean was then calculated for each region.

Units

scaled 0-1

6.73 Nutrient pollution trend

cw_nutrient_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cw_nutrient_trend.csv)

See description for nutrient pollution layer **Nutrient pollution**.

The inverse of the pressure data (1 - **Coastal nutrient pollution**) was used to estimate nutrient trends for the clean water goal. The proportional yearly change was estimated using a linear regression model of the most recent five years of data (i.e., slope divided by data from the earliest year included in the regression model). The slope was then multiplied by five to get the predicted change in 5 years.

Units

trend

6.74 Ocean acidification

cc_acid (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cc_acid.csv)

Pressure

Category: ecological

Subcategory: climate change

This pressure layer models the difference in global distribution of the aragonite saturation state (Ω_{arag}) of the ocean in the pre-industrial era and modern times. Global estimates through time (Feely et al. 2009) are modeled at 1-degree resolution. Changes in the saturation state can be attributed to changes in the concentration of CO_2 and thus we use the difference between the pre-industrial and modern times as a proxy for ocean acidification due to human influences. Values are rescaled from 0 to 1 using the threshold at which seawater becomes undersaturated, where $\Omega_{arag} = 1$.

Units

scaled 0-1

6.75 Offshore 3nm area

rgn_area_offshore3nm (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/rgn_area_offshore3nm.csv)

See **Region areas based on EEZ boundaries** layer for more information.

Area (km2) located from each region's land-sea interface to 3nm offshore.

Units

km2

6.76 Offshore coastal protected areas

lsp_prot_area_offshore3nm (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/lsp_prot_area_offshore3nm.csv)

This includes marine protected areas within 3nm offshore of the coastline.

Data is from the United Nations Environment Programme - World Conservation Monitoring Centre's World Database on Protected Areas (WDPA, http://www.protectedplanet.net (http://www.protectedplanet.net)). Data includes all nationally designated (e.g., National Parks, Nature Reserves) and internationally recognized protected areas (e.g., UNESCO World Heritage Sites, Ramsar Wetlands of International Importance) as an ESRI shapefile. We used only WDPA polygons (not points) with a status of "designated" (not "proposed"). These polygons were converted to a 500 m Mollweide raster by the value of the year in which the park was decreed "designated". For cases in which polygons overlapped, priority was given first to the parks with the earliest year. The total amount of protected area (km^2) was calculated for each year for: the entire eez, 3 nm offshore, and 1km inland (depending on the dimension being calculated).

Units

km2

6.77 OHI region id

rgn_global (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/rgn_global.csv)

OHI global region ID and name.

Units

label

6.78 Pathogen pollution

po_pathogens (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/po_pathogens.csv)

Pressure

Category: ecological

Subcategory: pollution

The percentage of the population with access to improved sanitation facilities (World Health Organization and United Nations Children's Fund, Joint Monitoring Programme, 2017) was used in combination with measurements of coastal population as a proxy for pathogens in coastal waters. Access to improved sanitation facilities is defined as the percentage of the population in a country with at least adequate access to disposal facilities that can effectively prevent human, animal, and insect contact with excreta. These data are a country-wide average (not specific to the coastal region). Percentages (0-100) for each country were rescaled to 0-1 based on a maximum target of 100% of the population with access to improved sanitation, and a minimum value of 0. Reference point was defined as the 99th quantile across year/region with no buffer and constrained to the first 10 years of data (vs. all available years of data).

Units

scaled 0-1

6.79 Pathogen pollution trend

cw_pathogen_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cw_pathogen_trend.csv)

See description of data and methods in **Pathogen pollution** layer.

The proportional yearly change in pathogen pressure values were estimated using a linear regression model of the most recent five years of data (i.e., slope divided by data from the earliest year included in the regression model). The slope was then multiplied by five to get the predicted change in 5 years.

Units

trend

6.80 Percent direct employment in tourism

tr_jobs_pct_tourism (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/tr_jobs_pct_tourism.csv)

World Travel & Tourism Council (https://www.wttc.org/datagateway (https://www.wttc.org/datagateway)) provides country data describing the percent employment in the travel and tourism sectors (such as hotels, airlines, airports, travel agents and leisure & recreation services that deal directly with tourists). We used the percent employment in “direct” tourism jobs as an indicator of the number of tourists visiting the coast.

Regions without data were gapfilled using the average values of UN geopolitical regions.

Units

proportion

6.81 Plastic trash trends

cw_trash_trend (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cw_trash_trend.csv)

Trend in trash was estimated using data on improperly disposed of plastics (Jambeck et al. 2016). Data are from the supplement, and describe mismanaged plastic waste in 2010 and projected mismanaged plastic waste in 2025. Using these data, we estimates proportional trash trends during a 5 year period as follows:

$$trend_{15year} = (value_{2025} - value_{2010})/value_{2010}$$

$$trend_{1year} = trend_{15year}/15$$

The trend_1year value was then multiplied by 5 to get the estimated proportional change in 5 years.

Missing data was gapfilled using a linear regression model with population as a predictor.

Units

trend

6.82 Poison fishing

np_cyanide (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/np_cyanide.csv)

Reefs at Risk Revisited (Burke et al. 2007) recorded the global presence of destructive artisanal poison (cyanide) fishing based on survey observations and expert opinion. We reclassified the log-scale scoring system for the poison rasters so 0 = 0, 100 = 1, 1000 = 2. The mean raster score was then determined for each OHI region. The poison values for each region were then summed to get the total.

Units

scaled 0-1

6.83 Region areas based on EEZ boundaries

rgn_area (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/rgn_area.csv)

Area (km^2) for each region’s EEZ-based boundary.

OHI offshore regions are based on exclusive economic zones (EEZ, VLIZ 2012). Unique country EEZs were typically used to define a region, except territorial regions were split from the administrative country. Many borders have been redrawn, such as the removal of UK claims around Cyprus. Gaps and extensions between this EEZ file and our land-sea mask were resolved through GIS operations (buffer, erase, and polygon neighbor analysis). Ocean area per region was calculated using geodesic area calculations on the region polygons in geographic coordinates. We exclude from regions the inland EEZs of the Caspian Sea and any disputed areas.

Units

km2

6.84 Regions

rgn_labels (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/rgn_labels.csv)

OHI region ids for eez (1-250) and fao high seas regions (260-278).

Units

label

6.85 Relative natural product harvest tonnes

np_harvest_tonnes_relative (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/np_harvest_tonnes_relative.csv)

See **Natural product harvest** layer for more information about these data.

Within each region, the harvest of each commodity was scaled relative to its maximum value across all years. The tonnes of each commodity is divided by the maximum value observed for the commodity in each region, with a 35% buffer applied to avoid penalizing yearly variation and to prevent overharvesting (i.e., max value times 0.65).

Units

proportion

6.86 Relative natural product harvest value

np_harvest_product_weight (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/np_harvest_product_weight.csv)

See **Natural product harvest** layer for more information about these data.

Within each region and year, the value (USD) of harvest of each commodity relative to total harvest value of six marine commodities (coral, fish oil, inedible seaweed and plants, shells, sponges, ornamental fish). Used to weight contribution of each product to final natural product status score.

Units

proportion

6.87 Sea level rise

cc_slr (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cc_slr.csv)

Pressure

Category: ecological

Subcategory: climate change

The sea level rise pressure layer is derived from satellite altimetry data (http://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/msla-mean-climatology.html (http://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/msla-mean-climatology.html)). Monthly mean sea level anomalies since 1993 track changes in sea level (mm) compared to a reference period from 1993-2012. Raw monthly data are provided on a 0.25x0.25 degree grid. These data were clipped to within 3 nautical miles of the coast, and monthly data layers were aggregated and averaged across pixels to compute mean sea level anomalies. The 99.99th quantile of raster values from all years was used as the reference point to rescale the layer from 0 to 1. All negative values were set to zero (i.e., no negative pressure), such that only positive sea level rise values mattered. The mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.88 Sea surface temperature

cc_sst (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cc_sst.csv)

Pressure

Category: ecological

Subcategory: climate change

Sea surface temperature (SST) data were obtained from the Coral Reef Temperature Anomaly Database (CoRTAD) (Casey et al. 2015), which is produced by the NOAA National Center for Environmental Information (NCEI) using 4.6 km (nominally 21 km^2 at the equator) Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 6 (v6 data (https://data.nodc.noaa.gov/cortad/Version6/)) SST data (http://www.nodc.noaa.gov/sog/cortad/ (http://www.nodc.noaa.gov/sog/cortad/)). Weekly SST data are used to compute the standard deviation (SD) of SST's per pixel across all years. We define an anomaly as exceeding the standard deviation of SSTs from the climatology for that location (i.e., grid cell) and week of the year. The frequency of weekly anomalies was calculated for each year in the dataset. We then quantified the difference between the number of anomalies in the 5 most recent years and the 5 oldest years in the dataset. The 99.99th quantile of raster values from all years was used as the reference point to rescale the layer from 0 to 1, and the mean value of the raster cells within each OHI region was calculated.

Because SST measurements are less reliable where there is persistent ice, we created an ice mask to identify places near the poles that were almost always covered by significant sea ice. The ice mask was generated primarily from the OSI/SAF Global Daily Sea Ice Concentration Reprocessing Data Set (accession.nodc.noaa.gov/0068294), which was regridded and made available in the Pathfinder V5.2 dataset. In Pathfinder, when the OSI/SAF data are unavailable, the sea ice concentrations from the NCDC Daily OI SST data (Reynolds et al. 2007) are included. For each day of the climatological year (1 through 366), we read in the daily sea ice fraction for that day from all of the years and averaged them to create a daily, sea-ice fraction climatology. We then identified grid cells that always contained a sea ice fraction of greater than 0.15 and masked them out of the analysis.

Units

scaled 0-1

6.89 Sectors in each region

le_sector_weight (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/le_sector_weight.csv)

Describes which livelihood and economy sectors are present in each region.

Units

value

6.90 Social Progress Index

res_spi (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/res_spi.csv)

Resilience

Category: social

The Social Progress Index (http://www.socialprogressimperative.org/global-index/ (http://www.socialprogressimperative.org/global-index/)) includes several quality of life measures. The SPI score is the average of 3 dimensions, and each dimension is the average of 4 components. Each component includes several indicators that are scaled from 0 to 100. When a region was missing 1 or more component, but not all of them, we used the aregImpute function from the Hmisc package to estimate the dimension value based on the available component values. Regions with no dimension/component data were estimated using a linear regression model with UN geopolitical region and WGI data as predictor variables. Uninhabited regions received no score.

Units

scaled 0-1

6.91 Strength of governance

wgi_all (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/wgi_all.csv)

Resilience

Category: social

The Worldwide Governance Indicator (WGI) is composed of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. These 6 aggregate indicators combine data from a variety of survey institutes, think tanks, NGOs, and international organizations to report on the relative governance of 213 economies worldwide. The WGI combines individual indicators through an Unobserved Components Model to produce the 6 dimensions of governance that range in value from approximately -2.5 to 2.5, have a normal distribution, a mean of zero, and a standard deviation of 1. We take an average of the six dimension scores to produce a single governance score for each country. Social pressure is then calculated as one minus this average WGI score.

WGI scores are provided for China/Hong Kong/Macao and Puerto Rico/Virgin Island, which are combine OHI regions. These scores were averaged, weighted by population.

Units

scaled 0-1

6.92 Subtidal hardbottom habitat destruction

hd_subtidal_hb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_subtidal_hb.csv)

Pressure

Category: ecological

Subcategory: habitat destruction

Reefs at Risk Revisited (Burke et al. 2007) recorded the global presence of destructive artisanal blast fishing based on survey observations and expert opinion. We reclassified the log-scale scoring system for the blast rasters, so 0 = 0, 100 = 1, 1000 = 2. The mean raster score was then determined for each OHI region. The blast values for each region were then summed to get the total.

Units

scaled 0-1

6.93 Subtidal soft bottom habitat destruction

hd_subtidal_sb (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/hd_subtidal_sb.csv)

Pressure

Category: ecological

Subcategory: habitat destruction

See **Habitat condition of softbottom** layer to get more information about this layer.

The Pressure score was calculated as one minus soft-bottom habitat condition.

Units

scaled 0-1

6.94 Targeted harvest of cetaceans and marine turtles

fp_targetharvest (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/fp_targetharvest.csv)

Pressure

Category: ecological

Subcategory: fishing pressure

This data layer describes the pressure on cetaceans and marine turtles for each country calculated using the FAO Global Capture Production Quantity dataset. We extracted all catch records from the FAO data for cetaceans or marine turtles and aggregated to create a total reported catch count for each region. The summed catch was rescaled from 0-1, using the 95th quantile across all years (including and prior to the assessment year) and regions (values > 1 were capped at 1).

Units

scaled 0-1

6.95 Tourism sustainability index

tr_sustainability (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/tr_sustainability.csv)

The Travel and Tourism Competitiveness Index is produced by the World Economic Forum and measures the factors and policies that make a country an attractive place to invest in the travel and tourism sector (WEF 2017 (http://reports.weforum.org/travel-and-tourism-competitiveness-report-2017/?doing_wp_cron=1536798155.3167469501495361328125)). The index analyzes 140 countries and scores each based on three sub-indices: human, cultural, and natural resources; business environment and infrastructure; and regulatory framework. These three sub-indices are in turn composed of 14 “pillars” of Travel & Tourism Competitiveness that are informed by a multitude of individual indicators based on the World Economic Forum’s annual Executive Opinion Survey and data from publically available sources: human, cultural, and natural resources (human resources, affinity for travel and tourism, natural resources, and cultural resources); business environment and infrastructure (air transport infrastructure, ground transport infrastructure, tourism infrastructure, ICT infrastructure, and price competitiveness in the industry); and regulatory framework (policy rules and regulations, environmental sustainability, safety and security, health and hygiene, and prioritization of travel and tourism). Because these indicators are meant to represent the overall quality and future potential of the tourism sector within a country, we assume they are representative of the long term sustainability of the tourism sector within each country. Values range from 1-6.

For countries not assessed, values were estimated using a linear regression model specific to each UN geopolitical region using per-capita GDP as a predictor variable.

Units

scaled 0-1

6.96 Uninhabited regions

uninhabited (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/uninhabited.csv)

This layer is a list of low and zero population regions based on Wikipedia.

Units

population

6.97 US State Department travel warnings

tr_travelwarnings (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/tr_travelwarnings.csv)

Travel advisories are from the U.S. State Department (https://travel.state.gov/content/passports/en/alertswarnings.html (https://travel.state.gov/content/passports/en/alertswarnings.html)). Penalty scores were based on the urgency of warning (‘Exercise Normal Precautions’= 1 (no penalty), ‘Exercise Increase Caution’= 1 (no penalty), ‘Reconsider Travel’=0.25, and ‘Do Not Travel’ = 0).

Units

scaled 0-1

6.98 UV radiation

cc_uv (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/cc_uv.csv)

Pressure

Category: ecological

Subcategory: climate change

The ultraviolet radiation (UV) pressure layer is derived from daily Local Noon Erythemal UV Irradiance (mW/m^2) data. The Aura/OMI satellite provides data at 1x1 degree resolution from September 2004 through present, spanning 180 degrees latitude and 360 degrees longitude. Raster data are provided in HDF5 format by the NASA Goddard Earth Sciences Data and Information Services Center (GESDISC, (http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omuvbd_v003.shtml (http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omuvbd_v003.shtml)). Raw data was downloaded, translated to GeoTIFFs using R and aggregated to weekly means.

This pressure measures the number of times the weekly average of each 1 degree cell exceeds the climatological mean + 1 standard deviation, defined as an anomalous value. The frequency of weekly anomalies was calculated for each year in the dataset. We then quantified the difference between the number of anomalies in the 5 most recent years and the 5 oldest years in the dataset. The 99.99th quantile of raster values from all years was used as the reference point to rescale the layer from 0 to 1, and the mean value of the raster cells within each OHI region was calculated.

Units

scaled 0-1

6.99 Weakness of governance

ss_wgi (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/ss_wgi.csv)

Pressure

Category: social

See **Strength of governance** for description of this layer.

When used as a social pressure, 1 minus the WGI (Worldwide Governance Indicator) is used.

Units

scaled 0-1

6.100 Weakness of social progress

ss_spi (https://github.com/OHI-Science/ohi-global/tree/draft/eez/layers/ss_spi.csv)

Pressure

Category: social

See **Social Progress Index** for description of this layer.

When used as a social pressure, 1 minus the SPI (Social Progress Index) is used.

Units

scaled 0-1

References

Allison, E.H. & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy*, **25**, 377–388.

Anderson, S. (2018). *Stock assessment methods for data-limited fisheries: Datalimited/datalimited*. datalimited.

Anderson, S.C., Cooper, A.B., Jensen, O.P., Minto, C., Thorson, J.T., Walsh, J.C., Afflerbach, J., Dickey-Collas, M., Kleisner, K.M., Longo, C., Osio, G.C., Ovando, D., Mosqueira, I., Rosenberg, A.A. & Selig, E.R. (2017). Improving estimates of population status and trend with superensemble models. *Fish and Fisheries*, n/a–n/a.

Attaran, M. (1986). Industrial diversity and economic performance in u.S. areas. *The Annals of Regional Science*, **20**, 44–54.

AVISO. (2018). Satellite alimetry data: Mean sea level rise. Satellite alimetry satelite altimetry data. URL https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html (https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html) [accessed 1 August 2018]

Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O.U., Swartz, B., Quental, T.B., Marshall, C., McGuire, J.L., Lindsey, E.L., Maguire, K.C., Mersey, B. & Ferrer, E.A. (2011). Has the earth's sixth mass extinction already arrived? *Nature*, **471**, 51–57.

Behrenfeld, M.J. & Falkowski, P.G. (1997). Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology and oceanography*, **42**, 1–20.

Bird species distribution maps of the world. version 7.0. (2017).

Borja, A., Bricker, S.B., Dauer, D.M., Demetriades, N.T., Ferreira, J.G., Forbes, A.T., Hutchings, P., Jia, X., Kenchington, R., Marques, J.C. & Zhu, C. (2008). Overview of integrative tools and methods in assessing ecological integrity in estuarine and coastal systems worldwide. *Marine Pollution Bulletin*, **56**, 1519–1537.

Bridgham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B. & Trettin, C. (2006). The carbon balance of north american wetlands. *Wetlands*, **26**, 889–916.

Bruno, J.F. & Selig, E.R. (2007). Regional decline of coral cover in the indo-pacific: Timing, extent, and subregional comparisons (R. Freckleton, Ed.). *PLoS ONE*, **2**, e711.

Burgass, M.J., Halpern, B.S., Nicholson, E. & Milner-Gulland, E.J. (2017). Navigating uncertainty in environmental composite indicators. *Ecological Indicators*, **75**, 268–278.

Burke, L., Reytar, K., Spadling, M., Perry, A., Cooper, E., Kushner, B., Selig, E., Starkhouse, B., Teleki, K., Waite, R., Wilkinson, C. & Young, T. (2011). *Reefs at risk - revisited*. World Resources Institute, Washington, D.C.

Butchart, S.H., Resit Akçakaya, H., Chanson, J., Baillie, J.E., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N. & Hilton-Taylor, C. (2007). Improvements to the red list index (D. Lusseau, Ed.). *PLoS ONE*, **2**, e140.

Cavalieri, D.J., Parkinson, C.L., Gloersen, P. & Zwally, H.J. (1996). *Sea ice concentrations from nimbus-7 SMMR and DMSP SSM/i-SSMIS passive microwave data, version 1*. NASA National Snow; Ice Data Center Distributed Active Archive Center, Boulder, Colorado USA.

Center For International Earth Science Information Network-CIESIN-Columbia University. (2017). Gridded population of the world, version 4 (GPWv4): Population density adjusted to match 2015 revision of UN WPP country totals, revision 10.

Cinner, J., Daw, T. & McCLANAHAN, T. (2009). Socioeconomic factors that affect artisanal fishers' readiness to exit a declining fishery. *Conservation Biology*, **23**, 124–130.

CITES. (2015). Member countries. URL https://cites.org/eng/disc/parties/index.php (https://cites.org/eng/disc/parties/index.php)

Claus, S., De Hauwere, N., Vanhoorne, B., Souza Dias, F., Oset Garcia, P., Hernandez, F. & Mees, J. (2012). Marine regions: Exclusive economic zones (v7). URL http://www.marineregions.org/ (http://www.marineregions.org/)

Convention on Biological Diversity. (2005). 3rd national report, survey results. URL https://www.cbd.int/convention/ (https://www.cbd.int/convention/) [accessed 13 April 2016]

Costello, C., Ovando, D., Clavelle, T., Strauss, C.K., Hilborn, R., Melnychuk, M.C., Branch, T.A., Gaines, S.D., Szuwalski, C.S., Cabral, R.B., Rader, D.N. & Leland, A. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the National Academy of Sciences*, **113**, 5125–5129.

Costello, C., Ovando, D., Hilborn, R., Gaines, S.D., Deschenes, O. & Lester, S.E. (2012). Status and solutions for the world's unassessed fisheries. *Science*, **338**, 517–520.

Dahl, T.E. (2011). *Status and trends of wetlands in the conterminous united states 2004 to 2009*. US Department of the Interior, US Fish; Wildlife Service, Fisheries; Habitat Conservation.

Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M. & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, **4**, 293–297.

Duarte, C.M. (2000). Marine biodiversity and ecosystem services: An elusive link. *Journal of Experimental Marine Biology and Ecology*, **250**, 117–131.

Eionet, E.E.A.(. (2008). EU habitats directive article 17 reporting, 2001-2006. URL http://bd.eionet.europa.eu/activities/Reporting/Article_17/reference_portal (http://bd.eionet.europa.eu/activities/Reporting/Article_17/reference_portal)

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G. & Reisser, J. (2014). Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLoS ONE*, **9**, e111913.

ESRI. (2010). Esri data and maps.

FAO Fisheries and Aquaculture Department. (2015). CWP handbook of fishery statistical standards. section h: FISHING AREAS FOR STATISTICAL PURPOSES.

Feely, R., Doney, S. & Cooley, S. (2009). Ocean acidification: Present conditions and future changes in a high-CO2 world. *Oceanography*, **22**, 36–47.

France, E. (2011). Électricité de france. URL https://www.edf.fr/ (https://www.edf.fr/)

Frazier, M., Longo, C. & Halpern, B.S. (2016). Mapping uncertainty due to missing data in the global ocean health index. *PLOS ONE*, **11**, e0160377.

Free, C. (2017). Mapping fish stock boundaries for the original ram myers stock-recruit database.

Froese, R., Branch, T.A., Proelß, A., Quaas, M., Sainsbury, K. & Zimmermann, C. (2011). Generic harvest control rules for european fisheries: Generic harvest control rules. *Fish and Fisheries*, **12**, 340–351.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J. & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data: Status and distributions of global mangroves. *Global Ecology and Biogeography*, **20**, 154–159.

Halpern, B.S., Frazier, M., Potapenko, J., Casey, K.S., Koenig, K., Longo, C., Lowndes, J.S., Rockwood, R.C., Selig, E.R., Selkoe, K.A. & Walbridge, S. (2015a). Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications*, **6**, 7615.

Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., Katona, S.K., Kleisner, K., Lester, S.E., O'Leary, J., Ranelletti, M., Rosenberg, A.A., Scarborough, C., Selig, E.R., Best, B.D., Brumbaugh, D.R., Chapin, F.S., Crowder, L.B., Daly, K.L., Doney, S.C., Elfes, C., Fogarty, M.J., Gaines, S.D., Jacobsen, K.I., Karrer, L.B., Leslie, H.M., Neeley, E., Pauly, D., Polasky, S., Ris, B., Martin, K.S., Stone, G.S., Sumaila, U.R. & Zeller, D. (2012). An index to assess the health and benefits of the global ocean. *Nature*.

Halpern, B.S., Longo, C., Lowndes, J.S.S., Best, B.D., Frazier, M., Katona, S.K., Kleisner, K.M., Rosenberg, A.A., Scarborough, C. & Selig, E.R. (2015b). Patterns and emerging trends in global ocean health. *PLoS ONE*, **10**, e0117863.

Halpern, B.S., Longo, C., Scarborough, C., Hardy, D., Best, B.D., Doney, S.C., Katona, S.K., McLeod, K.L., Rosenberg, A.A. & Samhouri, J.F. (2014). Assessing the health of the u.S. west coast with a regional-scale application of the ocean health index. *PLOS ONE*, **9**, e98995.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. & Watson, R. (2008). A global map of human impact on marine ecosystems. *Science*, **319**, 948–952.

Hamilton, S. & Casey, D. (2016). Creation of a high spatiotemporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecology and Biogeography*.

Hemminga, M.A. & Duarte, C.M. (2000). *Seagrass ecology*. Cambridge University Press.

Hoffmann, M., Hilton-Taylor, C., Angulo, A., Bohm, M., Brooks, T.M., Butchart, S.H.M., Carpenter, K.E., Chanson, J., Collen, B., Cox, N.A., Darwall, W.R.T., Dulvy, N.K., Harrison, L.R., Katariya, V., Pollock, C.M., Quader, S., Richman, N.I., Rodrigues, A.S.L., Tognelli, M.F., Vie, J.-C., Aguiar, J.M., Allen, D.J., Allen, G.R., Amori, G., Ananjeva, N.B., Andreone, F., Andrew, P., Ortiz, A.L.A., Baillie, J.E.M., Baldi, R., Bell, B.D., Biju, S.D., Bird, J.P., Black-Decima, P., Blanc, J.J., Bolanos, F., Bolivar-G., W., Burfield, I.J., Burton, J.A., Capper, D.R., Castro, F., Catullo, G., Cavanagh, R.D., Channing, A., Chao, N.L., Chenery, A.M., Chiozza, F., Clausnitzer, V., Collar, N.J., Collett, L.C., Collette, B.B., Fernandez, C.F.C., Craig, M.T., Crosby, M.J., Cumberlidge, N., Cuttelod, A., Derocher, A.E., Diesmos, A.C., Donaldson, J.S., Duckworth, J.W., Dutson, G., Dutta, S.K., Emslie, R.H., Farjon, A., Fowler, S., Freyhof, J., Garshelis, D.L., Gerlach, J., Gower, D.J., Grant, T.D., Hammerson, G.A., Harris, R.B., Heaney, L.R., Hedges, S.B., Hero, J.-M., Hughes, B., Hussain, S.A., Icochea M., J., Inger, R.F., Ishii, N., Iskandar, D.T., Jenkins, R.K.B., Kaneko, Y., Kottelat, M., Kovacs, K.M., Kuzmin, S.L., La Marca, E., Lamoreux, J.F., Lau, M.W.N., Lavilla, E.O., Leus, K., Lewison, R.L., Lichtenstein, G., Livingstone, S.R., Lukoschek, V., Mallon, D.P., McGowan, P.J.K., McIvor, A., Moehlman, P.D., Molur, S., Alonso, A.M., Musick, J.A., Nowell, K., Nussbaum, R.A., Olech, W., Orlov, N.L., Papenfuss, T.J., Parra-Olea, G., Perrin, W.F., Polidoro, B.A., Pourkazemi, M., Racey, P.A., Ragle, J.S., Ram, M., Rathbun, G., Reynolds, R.P., Rhodin, A.G.J., Richards, S.J., Rodriguez, L.O., Ron, S.R., Rondinini, C., Rylands, A.B., Sadovy de Mitcheson, Y., Sanciangco, J.C., Sanders, K.L., Santos-Barrera, G., Schipper, J., Self-Sullivan, C., Shi, Y., Shoemaker, A., Short, F.T., Sillero-Zubiri, C., Silvano, D.L., Smith, K.G., Smith, A.T., Snoeks, J., Stattersfield, A.J., Symes, A.J., Taber, A.B., Talukdar, B.K., Temple, H.J., Timmins, R., Tobias, J.A., Tsytsulina, K., Tweddle, D., Ubeda, C., Valenti, S.V., Paul van Dijk, P., Veiga, L.M., Veloso, A., Wege, D.C., Wilkinson, M., Williamson, E.A., Xie, F., Young, B.E., Akcakaya, H.R., Bennun, L., Blackburn, T.M., Boitani, L., Dublin, H.T., Fonseca, G.A.B. da, Gascon, C., Lacher, T.E., Mace, G.M., Mainka, S.A., McNeely, J.A., Mittermeier, R.A., Reid, G.M., Rodriguez, J.P., Rosenberg, A.A., Samways, M.J., Smart, J., Stein, B.A. & Stuart, S.N. (2010). The impact of conservation on the status of the world's vertebrates. *Science*, **330**, 1503–1509.

Homer, C., Huang, C., Yang, L., Wylie, B. & Coan, M. (2004). Development of a 2001 national land-cover database for the united states. *Photogrammetric Engineering & Remote Sensing*, **70**, 829–840.

Hovila, J., Arola, A. & Tamminen, J. (2013). OMUVBd: OMI/aura surface UVB irradiance and erythemal dose daily l3 global gridded 1.0 degree x 1.0 degree v3. NASA goddard space flight center, goddard earth sciences data and information services center (GES DISC). URL http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omuvbd_v003.shtml (http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omuvbd_v003.shtml) [accessed 24 July 2018]

Hughes, T.P. (2003). Climate change, human impacts, and the resilience of coral reefs. *Science*, **301**, 929–933.

Index, S.P. 2018 social progress index. 2018 social progress index. URL https://www.socialprogress.org/ (https://www.socialprogress.org/) [accessed 13 November 2018]

IUCN. (2016). *IUCN red list categories and criteria (version 2016-3)*. IUCN, Gland, Switzerland.

IUCN. (2018a). IUCN red list categories and criteria. The IUCN red list of threatened species. version 2018-1. URL http://www.iucnredlist.org/ (http://www.iucnredlist.org/) [accessed 17 August 2018]

IUCN. (2018). Protected planet: The world database on protected areas (WDPA) [on-line]. URL www.protectedplanet.net (www.protectedplanet.net) [accessed 2 July 2018]

IUCN. (2018b). The IUCN red list of threatened species. version 2018-1. URL http://www.iucnredlist.org/ (http://www.iucnredlist.org/)

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. & Law, K.L. (2015). Plastic waste inputs from land into the ocean. *Science*, **347**, 768–771.

Joint Nature Conservation Committee. (2004). Common standards monitoring guidance for saltmarsh habitats.

Joppa, L.N., O'Connor, B., Visconti, P., Smith, C., Geldmann, J., Hoffmann, M., Watson, J.E.M., Butchart, S.H.M., Virah-Sawmy, M., Halpern, B.S., Ahmed, S.E., Balmford, A., Sutherland, W.J., Harfoot, M., Hilton-Taylor, C., Foden, W., Minin, E.D., Pagad, S., Genovesi, P., Hutton, J. & Burgess, N.D. (2016). Filling in biodiversity threat gaps. *Science*, **352**, 416–418.

Kaufmann, D., Kraay, A. & Mastruzzi, M. (2010). *The worldwide governance indicators: Methodology and analytical issues*. Social Science Research Network, Rochester, NY.

Laffoley, D. & Grimsditch, G. (Eds.). (2009). *The management of natural coastal carbon sinks*. IUCN, Gland, Switzerland.

Le Quéré, C., Raupach, M.R., Canadell, J.G., Marland et al., G., Le Quéré et al., C., Le Quéré et al., C., Raupach, M.R., Canadell, J.G., Marland, G., Bopp, L., Ciais, P., Conway, T.J., Doney, S.C., Feely, R.A., Foster, P., Friedlingstein, P., Gurney, K., Houghton, R.A., House, J.I., Huntingford, C., Levy, P.E., Lomas, M.R., Majkut, J., Metzl, N., Ometto, J.P., Peters, G.P., Prentice, I.C., Randerson, J.T., Running, S.W., Sarmiento, J.L., Schuster, U., Sitch, S., Takahashi, T., Viovy, N., Werf, G.R. van der & Woodward, F.I. (2009). Trends in the sources and sinks of carbon dioxide. *Nature Geoscience*, **2**, 831–836.

Lewis, N., Day, J., Wilhelm, A., Wagner, D., Gaymer, D., Parks, J., Friedlander, A., White, S., Sheppard, C., Spalding, M., San Martin, G., Skeat, A., Taei, S., Teroroko, T. & Evans, J. (2017). Large-scale marine protected areas: Guidelines for design and management. best practice protected area guidelines series. **26**.

Liou, S.-M., Lo, S.-L. & Wang, S.-H. (2004). A generalized water quality index for taiwan. *Environmental Monitoring and Assessment*, **96**, 35–52.

Martell, S. & Froese, R. (2013). A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, **14**, 504–514.

McGoodwin, J., R. (2001). *Understanding the cultures of fishing communities: A key to fisheries management and food security*. FAO.

Molnar, J.L., Gamboa, R.L., Revenga, C. & Spalding, M.D. (2008). Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment*, **6**, 485–492.

Mora, C., Myers, R.A., Coll, M., Libralato, S., Pitcher, T.J., Sumaila, R.U., Zeller, D., Watson, R., Gaston, K.J. & Worm, B. (2009). Management effectiveness of the world's marine fisheries (C. Roberts, Ed.). *PLoS Biology*, **7**, e1000131.

Mora, C., Tittensor, D.P., Adl, S., Simpson, A.G.B. & Worm, B. (2011). How many species are there on earth and in the ocean? (G.M. Mace, Ed.). *PLoS Biology*, **9**, e1001127.

New Zealand Ministry for the Environment. (2007). *Environment new zealand 2007.* Ministry for the Environment, Wellington, N.Z.

NOAA. (2018). Coral reef temperature anomaly database (CoRTAD version 6). URL https://www.nodc.noaa.gov/sog/Cortad/ (https://www.nodc.noaa.gov/sog/Cortad/) [accessed 21 August 2018]

Oostendorp, R. & Freeman, R. (2012). The occupational wages around the world (OWW) database: Update for 1983-2008. URL http://www.nber.org/oww/ (http://www.nber.org/oww/) [accessed 4 January 2017]

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M. & Williams, S.L. (2006). A global crisis for seagrass ecosystems. *BioScience*, **56**, 987.

O'Connor, S., Campbell, R., Cortez, H., Knowles, T. & others. (2009). Whale watching worldwide: Tourism numbers, expenditures and expanding economic benefits, a special report from the international fund for animal welfare. *Yarmouth MA, USA, prepared by Economists at Large*, **228**.

O'Malley, R. Ocean productivity, standard VGPM. Ocean productivity. URL http://orca.science.oregonstate.edu/2160.by.4320.monthly.xyz.vgpm.m.chl.m.sst.php (http://orca.science.oregonstate.edu/2160.by.4320.monthly.xyz.vgpm.m.chl.m.sst.php) [accessed 31 July 2018]

Pitcher, T., Kalikoski, D. & Pramod, G. (2006). *Evaluations of compliance with the FAO (UN) code of conduct for responsible fisheries*. Fisheries Centre. University of British Columbia.

RAM. (2017). RAM legacy stock assessment database v3.8. RAM legacy stock assessment database. URL http://ramlegacy.org/ (http://ramlegacy.org/) [accessed 31 October 2017]

Ricard, D., Minto, C., Jensen, O.P. & Baum, J.K. (2012). Examining the knowledge base and status of commercially exploited marine species with the RAM legacy stock assessment database. *Fish and Fisheries*, **13**, 380–398.

Rosenberg, A., Fogarty, M., Cooper, A., Dickey-Collas, M., Fulton, B., Gutiérrez, N., Hyde, K., Kleisner, K., Kristiansen, Longo, C., Minte-Vera, C., Minto, C., Mosqueira, I., Osio, G., Ovando, D., Selig, E. & Thorson, J. (2014). *Developing new approaches to 116 global stock status assessment and maximum sustainable production of the seas.*

Sabine, C.L. & Tanhua, T. (2010). Estimation of anthropogenic CO_2 inventories in the ocean. *Annual Review of Marine Science*, **2**, 175–198.

Schaefer, M. (1954). Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bulletin of the International Americal Tropical Tuna Commission*, **1**, 26–56.

Schipper, J., Chanson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A.S.L., Stuart, S.N., Temple, H.J., Baillie, J., Boitani, L., Lacher, T.E., Mittermeier, R.A., Smith, A.T., Absolon, D., Aguiar, J.M., Amori, G., Bakkour, N., Baldi, R., Berridge, R.J., Bielby, J., Black, P.A., Blanc, J.J., Brooks, T.M., Burton, J.A., Butynski, T.M., Catullo, G., Chapman, R., Cokeliss, Z., Collen, B., Conroy, J., Cooke, J.G., Fonseca, G.A.B. da, Derocher, A.E., Dublin, H.T., Duckworth, J.W., Emmons, L., Emslie, R.H., Festa-Bianchet, M., Foster, M., Foster, S., Garshelis, D.L., Gates, C., Gimenez-Dixon, M., Gonzalez, S., Gonzalez-Maya, J.F., Good, T.C., Hammerson, G., Hammond, P.S., Happold, D., Happold, M., Hare, J., Harris, R.B., Hawkins, C.E., Haywood, M., Heaney, L.R., Hedges, S., Helgen, K.M., Hilton-Taylor, C., Hussain, S.A., Ishii, N., Jefferson, T.A., Jenkins, R.K.B., Johnston, C.H., Keith, M., Kingdon, J., Knox, D.H., Kovacs, K.M., Langhammer, P., Leus, K., Lewison, R., Lichtenstein, G., Lowry, L.F., Macavoy, Z., Mace, G.M., Mallon, D.P., Masi, M., McKnight, M.W., Medellin, R.A., Medici, P., Mills, G., Moehlman, P.D., Molur, S., Mora, A., Nowell, K., Oates, J.F., Olech, W., Oliver, W.R.L., Oprea, M., Patterson, B.D., Perrin, W.F., Polidoro, B.A., Pollock, C., Powel, A., Protas, Y., Racey, P., Ragle, J., Ramani, P., Rathbun, G., Reeves, R.R., Reilly, S.B., Reynolds, J.E., Rondinini, C., Rosell-Ambal, R.G., Rulli, M., Rylands, A.B., Savini, S., Schank, C.J., Sechrest, W., Self-Sullivan, C., Shoemaker, A., Sillero-Zubiri, C., De Silva, N., Smith, D.E., Srinivasulu, C., Stephenson, P.J., Strien, N. van, Talukdar, B.K., Taylor, B.L., Timmins, R., Tirira, D.G., Tognelli, M.F., Tsytsulina, K., Veiga, L.M., Vie, J.-C., Williamson, E.A., Wyatt, S.A., Xie, Y. & Young, B.E. (2008). The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science*, **322**, 225–230.

Schutte, V., Selig, E. & Bruno, J. (2010). Regional spatio-temporal trends in caribbean coral reef benthic communities. *Marine Ecology Progress Series*, **402**, 115–122.

Schwab, K. (2017a). *The global competitiveness report 2017–2018*. World Economic Forum.

Schwab, K. (2017b). *The travel & tourism competitiveness report 2017*. World Economic Forum.

Short, F.T., Polidoro, B., Livingstone, S.R., Carpenter, K.E., Bandeira, S., Bujang, J.S., Calumpong, H.P., Carruthers, T.J., Coles, R.G., Dennison, W.C., Erftemeijer, P.L., Fortes, M.D., Freeman, A.S., Jagtap, T., Kamal, A.H.M., Kendrick, G.A., Judson Kenworthy, W., La Nafie, Y.A., Nasution, I.M., Orth, R.J., Prathep, A., Sanciangco, J.C., Tussenbroek, B. van, Vergara, S.G., Waycott, M. & Zieman, J.C. (2011). Extinction risk assessment of the world's seagrass species. *Biological Conservation*, **144**, 1961–1971.

State, U.D. of. (2018). Travel alerts and warnings. URL https://travel.state.gov/content/travel/en/traveladvisories/traveladvisories.html (https://travel.state.gov/content/travel/en/traveladvisories/traveladvisories.html) [accessed 28 June 2010]

Stern, S., Wares, A. & Epner, T. (2018). *2018 social progress index: Methodology summary*.

Summerson, H.C. & Peterson, C.H. (1990). Recruitment failure of the bay scallop,Argopecten irradians concentricus, during the first red tide,Ptychodiscus brevis, outbreak recorded in north carolina. *Estuaries*, **13**, 322–331.

Tallis, H.T., Ricketts, T., Guerry, A., Wood, S., Sharp, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K. & others. (2011). *InVEST 2.2.1 user's guide*. The Natural Capital Project, Stanford University.

Thorbourne, R. (2011). Annopolis royal plant in canada.

Thorson, J.T., Minto, C., Minte-Vera, C.V., Kleisner, K.M., Longo, C. & Jacobson, L. (2013). A new role for effort dynamics in the theory of harvested populations and data-poor stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences*, **70**, 1829–1844.

TRC. (2004). *Inventory of coastal areas of local or regional significance in the taranaki region*. Taranaki Regional Council, Stratford.

Trujillo, P. (2008). Using a mariculture sustainability index to rank countries' performance. *Fisheries centre research reports* (eds J. Alder & D. Pauly). Fisheries Centre Research Reports, University of British Columbia, Vancouver, Canada.

UNDP. (2010). *Human development report 2010 –the real wealth of nations: Pathways to human development*. United Nations Development Programme (UNDP).

UNEP-WCMC. (2015). World database on protected areas user manual.

UNEP-WCMC & Short, F. (2005). *Global distribution of seagrasses (version 3). third update to the data layer used in green and short (2003), superseding version 2.* UNEP World Conservation Monitoring Centre, Cambridge, UK.

United Nations. (2017). FAO - commodity production and trade. FAO - commodities data. URL http://ref.data.fao.org/dataset?entryId=aea93578-9b01-4448-9305-917348ca00b2&tab=metadata (http://ref.data.fao.org/dataset?entryId=aea93578-9b01-4448-9305-917348ca00b2&tab=metadata) [accessed 12 May 2018]

United Nations. (2016a). FAO fisheries & aquaculture - fishery statistical collections - fishery commodities and trade. URL http://www.fao.org/fishery/statistics/global-commodities-production/en (http://www.fao.org/fishery/statistics/global-commodities-production/en) [accessed 29 June 2016]

United Nations. (2013a). FAO fisheries & aquaculture - fishery statistical collections - fishery commodities and trade. URL http://www.fao.org/fishery/statistics/global-commodities-production/en (http://www.fao.org/fishery/statistics/global-commodities-production/en)

United Nations. (2016b). FAO fisheries & aquaculture - fishery statistical collections - global aquaculture production. URL http://www.fao.org/fishery/statistics/global-aquaculture-production/en (http://www.fao.org/fishery/statistics/global-aquaculture-production/en) [accessed 29 June 2016]

United Nations. (2013b). FAO fisheries & aquaculture - fishery statistical collections - global aquaculture production. URL http://www.fao.org/fishery/statistics/global-aquaculture-production/en (http://www.fao.org/fishery/statistics/global-aquaculture-production/en)

United Nations. (2018a). FAO fisheries & aquaculture - fishery statistical collections - global aquaculture production. FAO fisheries & aquaculture - fishery statistical collections - global aquaculture production. URL http://ref.data.fao.org/dataset?entryId=033ae7cf-b322-4dc5-8dfe-140140c56008&tab=metadata (http://ref.data.fao.org/dataset?entryId=033ae7cf-b322-4dc5-8dfe-140140c56008&tab=metadata) [accessed 11 April 2018]

United Nations. (2016c). FAO fisheries & aquaculture - fishery statistical collections - global capture production. URL http://www.fao.org/fishery/statistics/global-capture-production/en (http://www.fao.org/fishery/statistics/global-capture-production/en) [accessed 29 June 2016]

United Nations. (2013c). FAO fisheries & aquaculture - fishery statistical collections - global capture production. URL http://www.fao.org/fishery/statistics/global-capture-production/en (http://www.fao.org/fishery/statistics/global-capture-production/en)

United Nations. (2018b). FAO FishStatJ - global capture production. FAO FishStatJ - global capture production. URL http://www.fao.org/fishery/statistics/software/fishstatj/en#downlApp (http://www.fao.org/fishery/statistics/software/fishstatj/en#downlApp) [accessed 1 August 2018]

United Nations. (2016d). FAO statistics division - inputs. URL http://faostat3.fao.org/browse/R/*/E (http://faostat3.fao.org/browse/R/*/E)

United Nations. (2010). FAOSTAT. URL http://www.fao.org/faostat/en/#home (http://www.fao.org/faostat/en/#home)

United Nations. (2012). Statistics division - energy statistics. URL http://unstats.un.org/unsd/energy/edbase.htm (http://unstats.un.org/unsd/energy/edbase.htm)

United Nations. (2013d). Statistics division - standard country and area codes classifications (m49). URL http://unstats.un.org/unsd/methods/m49/m49regin.htm (http://unstats.un.org/unsd/methods/m49/m49regin.htm) [accessed 13 April 2016]

United Nations. (2007). The world's mangroves 1980-2005. FAO forestry paper 153.

United Nations personal communication. (2011). FAO fisheries & aquaculture - fishery statistical collections - global number of fishers. URL http://www.fao.org/fishery/statistics/global-fishers/en (http://www.fao.org/fishery/statistics/global-fishers/en)

Watson, R. & Tidd, A. (2018). Mapping nearly a century and a half of global marine fishing: 1869–2015. **93**, 171–177.

Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T. & Williams, S.L. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences*, **106**, 12377–12381.

WHO-UNICEF. (2017). Joint monitoring programme (JMP) for water supply and sanitation. Joint monitoring programme (JMP) for water supply and sanitation. URL https://washdata.org/data (https://washdata.org/data) [accessed 1 May 2018]

Wikipedia. URL https://www.wikipedia.org/ (https://www.wikipedia.org/) [accessed 15 November 2018]

World Bank. (2014a). GDP (current US$). URL http://data.worldbank.org/indicator/%20NY.GDP.MKTP.CD (http://data.worldbank.org/indicator/%20NY.GDP.MKTP.CD)

World Bank. (2017). GDP per capita, PPP (constant 2011 international $). GDP per capita, PPP (constant 2011 international $). URL https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD (https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD) [accessed 23 July 2018]

World Bank. (2014b). Labor force, total. URL http://data.worldbank.org/indicator/SL.TLF.TOTL.IN (http://data.worldbank.org/indicator/SL.TLF.TOTL.IN)

World Bank. (2016). Population, total. URL http://data.worldbank.org/indicator/SP.POP.TOTL (http://data.worldbank.org/indicator/SP.POP.TOTL)

World Bank. (2014c). Unemployment, total (% of total labor force) (modeled ILO estimate). URL http://data.worldbank.org/indicator/SL.UEM.TOTL.ZS (http://data.worldbank.org/indicator/SL.UEM.TOTL.ZS)

World Bank. (2018). Worldwide governance indicators (WGI) data catalog. URL https://datacatalog.worldbank.org/dataset/worldwide-governance-indicators (https://datacatalog.worldbank.org/dataset/worldwide-governance-indicators) [accessed 13 November 2018]

WTTC. (2013). World travel and tourism council. URL www.wttc.org/research/economicimpact-research/methodology/ (www.wttc.org/research/economicimpact-research/methodology/)

WTTC. (2017). World travel and tourism council. World travel and tourism council. URL https://www.wttc.org/datagateway (https://www.wttc.org/datagateway) [accessed 12 July 2018]

Zeller, D., Palomares, M.L.D., Tavakolie, A., Ang, M., Belhabib, D., Cheung, W.W.L., Lam, V.W.Y., Sy, E., Tsui, G., Zylich, K. & Pauly, D. (2016). Still catching attention: Sea around us reconstructed global catch data, their spatial expression and public accessibility. *Marine Policy*, **70**, 145–152.