Ocean Health Index+ Assessment for Israel's Mediterranean Coast

SUPPLEMENTARY INFORMATION

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Overview

Following is a brief summary of the conceptual framework of the Ocean Health Index (OHI, or 'the Index'). We will focus on explaining and detailing differences between this independently-led local analysis (OHI+) and the global assessment[1]. Additional details can be found in the supporting documentation for the global study.

Conceptual Framework: Setting Reference Points

The Index assesses the current status and likely future state of the ocean based on ten goals for a healthy ocean, and then averages the scores to give a single Index score for the assessment. The current status is the present value relative to a specific reference point, with reference points established according to Samhouri et al.[2].

The process of determining reference points is both scientific and socio-political[2]. Science can provide information on thresholds or sustainable limits of delivering a goal, but we often do not know enough about such limits. Regardless, setting reference points is ultimately a social and political choice. Few examples can help illustrate this process. For mariculture, we know that appropriate reference points are both a function of sustainable production densities (an active area of research) and the total proportion of suitable coastal area available for mariculture (almost entirely a social decision). For habitat-based goals (such as biodiversity and coastal protection), setting reference points requires information on the extent of habitats in the past (which is often poorly known) and social decisions about how much habitat restoration is feasible and/or desired. For species-based goals (iconic species and species biodiversity), science provides a wealth of information about how to assess the viability of individual species, but it is ultimately a social decision as to whether reference points should be set at pristine conditions, impacted but sustainable populations, or whether some level of threat or loss to species should be allowed.

The approach to setting reference points for several of the goals was changed relative to approaches used in the global assessment (see Table 1), by adopting reference points set by government officials, when available. In the goal descriptions below we provide details on how and why we selected each reference point. This transparency allows decision makers who may be interested in using the Index to evaluate and decide whether they agree with the reference points or whether they would choose to change them instead.

In the descriptions below, we make an effort to clearly articulate where and why such choices of reference points were made, and note that local assessments of the Index, such as those carried out here, could develop parameter values unique to the region, based on input from community members, stakeholders, and decision makers.

Table 1: Comparison of type of reference points used to calculate the status of each goal and sub-goal in the global (Halpern et al. 2012) and Israeli Mediterranean local analyses.

Goal	**Sub-Goal**	**Global Reference Point Type**	**Local Reference Point Type (if different)**
Food Provision (x_{FP})	Fisheries (x_{FIS})	Functional Relationship	
	Mariculture (x_{MAR})	Spatial Comparison	Established Target
Artisanal Fishing Opportunities (x_{AO})		Functional Relationship	Functional Relationship
Coastal Protection (x_{CP})		Temporal Comparison (historical benchmark)	
Coastal Livelihoods and Economies (x_{LE})	Livelihoods (x_{LIV})	Temporal Comparison (historical benchmark)	
	Economies (x_{ECO})	Temporal Comparison (moving target) + Spatial Comparison	Temporal Comparison (moving target)
Tourism and Recreation (x_{TR})		Spatial Comparison	Temporal Comparison (moving target)
Sense of Place (x_{SP})	Iconic Species (x_{ICO})	Established Target	
	Lasting Special Places (x_{LSP})	Established Target	
Clean Waters (x_{CW})		Established Target	
Biodiversity (x_{BD})	Species (x_{SPP})	Established Target	
	Habitats (x_{HAB})	Temporal Comparison (historical benchmark)	Temporal Comparison (historical benchmark)+ Established target

Reporting Units

The Israeli EEZ is bounded by Lebanese, Cypriot, Egyptian and Gaza waters, extending to ca. 97 nm offshore. We divided the Israeli Mediterranean coastal and EEZ waters into six regions based on administrative (i.e. district) boundaries and Haifa Bay (a separate biogeographic province) as depicted in Figure 1. To produce the spatial boundaries of these reporting units (i.e., the Geographical Information System (GIS) spatial data associated with them) we first extracted the district map from the Ministry of Interior's computerized database, and extended the coastal district division lines to

Israel's Exclusive Economic Zone (EEZ) boundaries. To compensate for the concave coastline and the divergence of the extended lines, we adjusted the boundary between the two northernmost regions to be parallel with the EEZ boundary, so that the ratio between the regions and their land surface area would be roughly similar.

We constructed a high-resolution land-sea interface (i.e., coastline) based on 25 cm orthorectified aerial images (Survey of Israel 2012). We then computed an offshore 3 nautical miles (nmi) and 12 nmi boundary. (Israeli territorial waters) per district for use with some goals, and used the rest of the outer EEZ extent (about 97nmi) for use with other goals. The intersections of the EEZ waters for Israel, the seaward ranges of five coastal districts and the Haifa Bay region to form the six Israeli Mediterranean regions:

1-South, 2-Haifa, 3-Haifa Bay, 4-Center, 5-North, 6-Tel Aviv

In this assessment, our focus is on the entire EEZ and territorial waters(i.e., the 'study area'). The division into these six regions (i.e., regions) is somewhat artificial due to the small coastline (under 200 km), but we account for the fact that different goals play out at different scales. As such, our assessment represents a combination of information from within state waters as well as information that includes the full extent out to the EEZ boundary. Practically, this means that some goals are assessed against a reference point that incorporates the area out to the boundary of the EEZ (e.g., fisheries, biodiversity) while other goals are assessed for area within nearshore territorial water boundaries (e.g., clean water, mariculture), even though the assessments represent the score for the goal for the entire area out to the EEZ boundary.

The spatial scale by which each goal and sub-goal is calculated is described in Table 2, and in more detail in goal model descriptions. Overall Israeli Mediterranean scores are the EEZ area-weighted average of scores from all six regions.

Figure 1: Reporting units (regions) of the Israeli Mediterranean OHI+ assessment. Overall Israeli Mediterranean scores are the EEZ area-weighted average of scores from all six districts: 1-South, 2-Haifa, 3-Haifa Bay, 4- Center, 5-North, 6-Tel Aviv

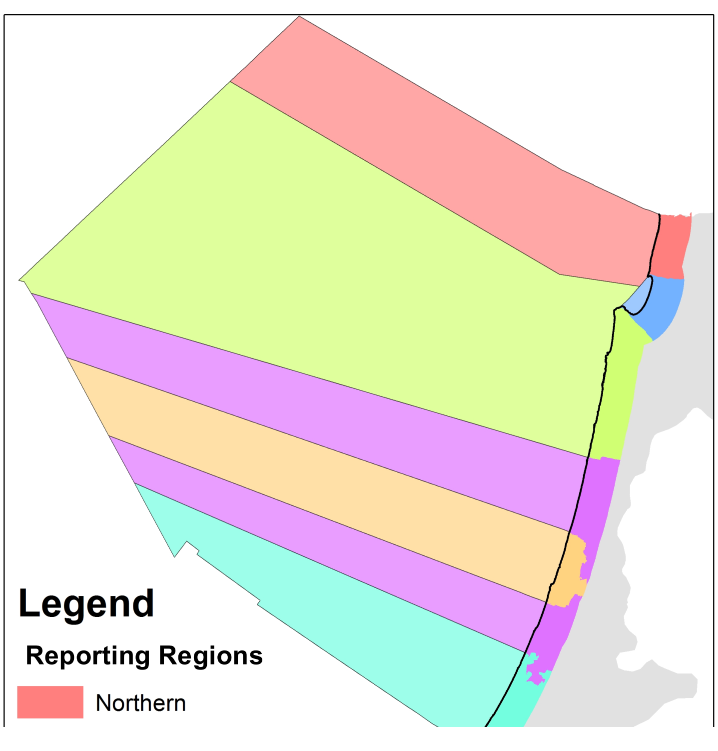

Table 2: Scale according to which each goal primarily delivers its value, and according to which reference points are set (i.e., these scales determine the area used to assess the current status relative to a reference point). EEZ is the region offshore waters to ca. 97 nm for all districts combined; Territorial waters are offshore waters to 12 nm for all districts combined; Coastal waters are offshore waters to 3 nm for each district individually; and Region is land-based data for each Region individually.

Goal	Sub-Goal	Primary Scale of Goal
Food Provision	Fisheries	EEZ
	Mariculture	Territorial waters
Artisanal Fishing Opportunities		Territorial waters
Coastal Protection		Region
Coastal Livelihoods and Economies	Livelihoods	Region
	Economies	Region
Tourism and Recreation		Region
Sense of Place	Iconic Species	EEZ
	Lasting Special Places	Region Coastal waters
Clean Waters		Region Coastal waters
Biodiversity	Species	EEZ
	Habitats	Coastal waters

Several datasets are at a beach-level resolution, so we assigned each beach to one of the six regions (Figure 1). For our spatial analyses, we use an Israel Transverse Mercator Conformal Cylindrical projection (centered at 35.2° longitude) and Geodetic Reference System (GRS) 1980 data.

Methods: Goal-Specific Models

A. Carbon Storage

The decision to exclude carbon storage from the Index calculations was based on two main factors. The first is that there are no data available on the only carbon-fixing ecosystem found in the Israeli Mediterranean, the seagrass beds. There have been sightings of some patches of seagrass, but these have never been documented or mapped; this habitat seems to be rare. Another reason for not including carbon storage in the Index is the fact that the Levant basin of the eastern Mediterranean is considered ultra-oligotrophic, characterized by extremely low productivity. For these reasons, the carbon storage goal was removed from this assessment.

B. Food Provision

The aim of this goal is to maximize the sustainable harvest of seafood in regional waters from wild-caught fisheries and mariculture. Wild-caught harvests must remain below levels that would compromise the resource and future harvest, but the amount of seafood harvested should be maximized within the bounds of sustainability, i.e., maximum sustainable yield (MSY). Similarly, mariculture practices must not inhibit the future production of seafood in the area, i.e. they must engage in sustainable practices, while maximizing the amount of mariculture that is possible and desired for a coastline that has many other uses as well. Because fisheries and mariculture are separate industries with very different features, we track each separately as a unique sub-goal before combining them into the Food Provision goal.

Fisheries: Israeli fishery is composed of about 40 different fish species; however, the available documentation over the last 10 years includes 10 species and about nine other taxonomic groups (Table 3). Since the 1990's, commercial fishery has seen stable landings, but catch-per-unit effort has persistently declined[3].

The status of the Fisheries sub-goal (x_{FIS}) was calculated according to the 2013 OHI Global Assessment[4], using data from fisheries in Israel from 1950 to 2010, processed by Edelist [3].

Table 3: Full taxonomy list including at least 10 years of data, used in the Fisheries sub-goal.

Taxa
Argyrosomus regius
Boops boops
Carangidae
Cephalopoda
Elasmobranchii
Epinephelus
Euthynnus alletteratus
Marine animals
Marsupenaeus japonicus
Merluccius merluccius
Mugilidae
Mullidae
Nemipterus randalli
Penaeidae
Sardinella gibbosa
Saurida undosquamis
Scomber japonicus
Seriola dumerili
Sphyraena

The trend was calculated as the slope of the status status scores between 2005-2010. Most of the ecological and social pressures included in the Index were considered to have an impact on fisheries, noted in Table 11, as were most of the resilience measures, as indicated in Table 13.

Mariculture: The status of the Mariculture sub-goal was calculated as the sustainable production of finfish biomass from mariculture relative to a target level of production for Israel. Species considered in the analysis were limited to one (*Sparus aurata*), because this species comprises nearly all (an estimated 99%) of the current mariculture production of seafood in Israel. Mariculture is regulated centrally for the whole of Israel and is currently legally carried out in specific areas of the Southern region. As such, the score for South was applied to all other regions. Finfish mariculture activities for restocking or restoration purposes are not included in this assessment.

The Mariculture sub-goal (x_{MAR}) is calculated as the current harvested finfish yield (Y_c) relative to the official target yield by the year 2020 (Y_{2020}), and multiplied by S_i, the sustainability score for *Sparus aurata,* such that:

(Equation 1)

$$x_{MAR} = \frac{Y_C * Si}{Y_{2020}}$$

Y_{2020} is the targeted production increase by the year 2020 established by Fishery official at the Israeli Ministry of Agriculture (8,500 tons of finfish, 350% growth).

This desired 350% increase is central planning based on growing domestic seafood consumption, current technology, and market demand, with all six regions in Israel treated as a single aggregate region and thus receiving the same score.

The sustainability score (S_i) for *Sparus aurata* (0.56) comes from the Mariculture Sustainability Index (MSI) [4a] and is the average of three sub-indicators used in the MSI: wastewater treatment, the origin of feed, and the origin of seed. The three specific sub-indicators were chosen because they reflect the long-term sustainability of the mariculture practice, but are not reflective of the impacts the mariculture practices may have on the surrounding environment or species, as such impacts would not hinder the future production and sustainability of the Mariculture sub-goal itself even though they might affect the delivery of benefits from other goals. See Table 10 for the MSI score applied to the finfish species harvested in Israel.

The trend was calculated as the slope of the actual shellfish production values from 2009 to 2013. Pressures included in the calculation of this goal are indicated in Table 11. Resilience measures are indicated in Table 13.

Combining Sub-Goals: The two sub-goals for the Food Provision goal were aggregated to produce a single goal score based on a proportional yield-weighted average, such that:

$$x_{FP} = \left(w_{FP} * x_{FIS}\right) + (1 - w_{FP})x_{MAR} \quad \text{(Equation 2)}$$

$$w_{FP} = \frac{C_T}{\left(C_T + Y_r\right)}, \quad \text{(Equation 3)}$$

where *w* is the weighting applied to each sub-goal based on the relative contribution of C_T, the total wild-caught yield of all species in the last available data year (2012), and Y_r, the current sustainably-harvested finfish yield in 2012 to overall food provision. In 2012 the yield from Mariculture equaled the wild-caught fishery landings, thus *w* (FIS) = 0.5.

C. Artisanal Fishing Opportunities

Artisanal Fishing, also known as small-scale fishing, accounts for about 50% of total fish landings in Israel. These landings are partly captured in the Fisheries sub-goal above due to a lack of species-specific data collection. In this goal we measure the opportunity to engage in the practice of artisanal fishing for cultural and/or economic purposes.

In the global model[1] this was assessed as a function of the need (assessed using poverty indicators), and the accessibility (assessed through institutional measures that support small-scale fishing), with a place-holder for stock status (which could not be assessed at global scales for artisanal-scale fishing). For Israel, as in the case of Brazil[5], we consider that the primary driver of artisanal opportunity is the availability of fish to capture (i.e. the condition of the stocks). Access to fishing in Israel is largely open because permits and regulations from the Ministry of Fisheries are not considered restrictive, and in most cases, neither is physical access.

The Status for this goal (X_{AO}) is therefore measured simply as:

$$X_{AO} = S_I \quad \text{(Equation 4)}$$

where S_I is a sustainability index calculated using the exploitation status of species (Table 5). The reference point for this goal is an established target of 1.0, that is, all stocks are categorized as either Developing or Fully Exploited. Ten coastal fish species, for which we have data, were considered possible targets of artisanal fishing activities. A caveat of the calculation is in the data source. Most of the data attained by the Israeli

Fisheries is from the trawl industry, and little is reported from coastal fishermen. The following species were selected after filtering the data for coastal species only.

Table 4: Coastal fish families and species used in the assessment of Artisanal Fishing Opportunities Goal

Coastal fish species
Argyrosomus regius
Epinephelus spp. (mixed)
Euthynnus alletteratus
Mugilidae
Sardinella spp. (mostly *aurita*)
Scomber japonicus
Seriola dumerili
Siganus spp.(mostly rivulatus)
Soleidae (mostly *Solea solea*)
Sphyraenidae (mostly *chrysotaenia*)

Table 5: Definitions and weights (*w*) assigned for each category of exploitations status

Exploitation Category	w	Definition
Developing	1.0	Stock landings have not reached a peak or peak occurs in the last year of the times series.
Fully exploited	1.0	Stock landings are between 50-100% of peak.
Overexploited	0.5	Stock landings are between 10-50% of peak.
Collapsed	0.0	Stock landings are < 10% of peak and recent trend is <0.
Rebuilding	0.25	Stock landings are between 10-50% of peak and recent trend is > 0.

The trend was calculated as the slope of the status scores from 2006-2010.
The model is currently calculated at the national-scale, and the same score is assigned to each coastal region. Slight variations in region scores is due to the effect of pressures and resilience on goal scores. Assessment of this goal could be greatly improved if reliable region-level landings data were available.
Pressures included in the calculation of this goal are indicated in Table 11. Resilience measures included water pollution enforcement and compliance scores, as well as the social resilience measures indicated in Table 13.

D. Biodiversity

People value marine biodiversity for its existence value. In addition, biodiversity can play a supporting role in the provision and sustainability of many other public goals; however this supporting role is not captured here. Instead, it is included in the resilience dimension, which is used to calculate the likely future state of this Goal, and for other public goals. In this assessment, we measured biodiversity through two sub-goals: habitats and species. Because the status of only a small portion of species has been assessed, we also measure the status of habitats as a proxy for the many species that rely upon these habitats. A simple average of these two sub-goal scores was used to obtain a single biodiversity goal score.

Species Sub-Goal: As was done in the global analysis, species status was calculated using each species' conservation risk category, as determined by the International Union for Conservation of Nature (IUCN). A list of species was composed based on Galil et al. [6], and was updated with data for marine mammals from the Israel Marine Mammal Research and Assistance Center (IMMRAC). Chondrichthyes (Barash pers. comm.) and marine turtles[7] (Appendix 1) comprising 762 species. This species list was crossed-referenced with the IUCN Global Marine Species Assessment. Assessment for all species for which distribution maps were available (from a global 0.5° grid) were retrieved. For those species prevalent in the study area that were not included in the distribution maps in the Mediterranean, data from assessments in the Black Seas were used. Additional data gap filling was done according to global assessment data. This resulted in a list of 249 species found in the IUCN Species Assessment, with status data for 206 of the species. Although this is a small sub-sample of the actual marine species present in the range, it represents the most comprehensive species status dataset available for the region, and it is used as a proxy of overall species status in the area.

The target reference point for this goal is to have all species within the region classified with a risk status of Least Concern. This goal also requires setting a lower limit (i.e., when status = 0), because setting this lower bound as the point at which every single species is gone is not meaningful to human values. Instead, we set this lower bound at when 75% of species are extinct, a level comparable to the five geologically documented mass extinctions[7a]. This score could also result from fewer extinct species, but from more species in highly threatened categories; here we treat these scenarios equivalently. Weights for each risk category are assigned to species by their established IUCN risk category, based on the weighting scheme developed by Butchart et al[7b]. (See Table 6 for IUCN risk categories and weights). The original weighting scheme developed by Butchart et al. [7a] to quantify extinction risk, which ranged from 0-5 (extinct = 5), was rescaled from 0-1 and inverted to represent a lack of extinction risk for our purposes. See Halpern et al.[1] for the full methodological description.

Table 6: IUCN risk categories and weights derived from weights developed by Butchart et al. (2007).

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

The status for the Species sub-goal was calculated as the area-weighted average species risk status, as was done by Halpern et al.[1].The threat category weight (*w*) for each species (*i*) is summed for all of the *M* 0.5 degree grid cells (*c*) and divided by the total number of species (*N*) within each cell. The resulting score is an area-weighted mean across all species *i* within cell *k*. These values are summed across all cells in each *k* region and divided by the total area within the region (A_T) such that:

$$x_{SPP} = \frac{\sum_{k=1}^{M}\left(\frac{\sum_{i=1}^{N} w_{i,k}}{N}\right) * A_c}{A_T} \qquad \text{(Equation 5)}$$

The trend was calculated using available trend values assigned by IUCN for assessed species (N=250), with increasing populations receiving a score of 0.5, stable populations a score of 0, and decreasing populations receiving a -0.5 score. Trends were aggregated in the same way as the status scores above. All pressures were applied in the Species sub-goal, except human pathogens and gas prices (see Table 11 for full list). Most resilience measures were also applied, except climate change regulations and gas prices. In addition, we did not include the ecological integrity measure, as it utilizes the same IUCN risk category data applied in the status calculation (see Table 13 for full list).

Habitats Sub-Goal: The status of the Habitat sub-goal (x_{HAB}) was calculated using publicly available data for habitats: sand dunes and soft-bottom habitats. These habitats were chosen because they represent a large portion of regional coastal and marine environments and because they have data with relatively comprehensive temporal and spatial coverage. Other important habitats such as rocky reefs and the rocky intertidal could not be included due to lack of data on current and/or past spatial extent and condition. The status of the Habitat sub-goal (x_{HAB}) is calculated based on the current condition (C_C) compared to the reference condition (C_r) of each k habitat such that:

$$x_{HAB} = \frac{\sum_{1}^{k}\left(\frac{C_C}{C_r}\right)}{k} \qquad \text{(Equation 6)}$$

In the global study[1], the current condition of salt marshes, seagrasses, mangroves and corals was compared to a reference year that is intended to represent optimal conditions (1980 for salt marshes and sand dunes, varied by site for seagrasses). However, reliable, comprehensive satellite photos were available from 1970, which enabled an evaluation of the habitat extent of the sand dunes. Beach sand mining has been prohibited by law since 1964. This was before most of the coastal infrastructures were built that caused changes to the littoral sand transport. The areas of the coastal infrastructures themselves were removed from this evaluation, since restoring these areas is considered an unrealistic goal under current conditions. For soft-bottom habitat we utilized relevant pressure as a proxy of habitat conditions. These reference points were selected to provide ambitious yet realistic goals, following principles for desirable reference point qualities[2]. See Habitat Destruction, Sub-tidal Soft-Bottom description for full data source information and modeling details.

E. Coastal Protection

This goal assesses the role of marine associated habitats in protecting coastal areas that people value, both inhabited (e.g. cities) and uninhabited (e.g. park). In the Israeli Mediterranean assessment we measured the role of sand dunes, since other important habitats, such as rocky reefs and the rocky intertidal flats, could not be included due to lack of data on current and/or past spatial extent and condition (we do not evaluate protection afforded by human-made or geological features). Ideally, one would also know the value of the land and vulnerability of inhabitants being protected by these habitats. We currently do not have this information, and thus this goal assesses the potential of coastal protection provided by habitats.

The status of this goal was calculated as the condition of each habitat relative to a reference condition and the ranked protective ability of each habitat, such that:

$$x_{CP} = \sum_{k}\left(\alpha_k \frac{C_{c,k}}{C_{r,k}}\right) \qquad \text{(Equation 7)}$$

$$\alpha_k = \frac{w_k A_k}{\sum_k (w_k A_k)} \quad \text{(Equation 8)}$$

$$w_k = \frac{r_k}{\sum_k r_k} \quad \text{(Equation 9)}$$

where α_k is the area-weighted rank for habitat k, r_k is the protective rank for habitat k, A_k is the area of habitat k, and C_k is the current (c) and reference (r) conditions for habitat k. Protective habitat ranks are the same as those used in the global analysis and come from the Natural Capital Project (Natural Capital Project 2011), which ranks the protective ability of sand dunes as 2.

Sand dune extent and trend were calculated in the same way as was done in the biodiversity model. See Table 11 for pressure details and Table 13 for resilience measures.

F. Sense of Place

The Sense of Place goal aims to capture aspects of the coastal and marine system that contribute to a person's sense of cultural identity. This goal is difficult to measure quantitatively because many attributes that define one's cultural identity are not measured. Several reasonable proxy measures of aspects of sense of place do exist, and we used those in this study. To measure how well this goal is being delivered, we focused on two components of how people connect with the ocean: iconic species and lasting special places. The overall goal score for sense of place is then the arithmetic mean of the two sub-goals scores.

Iconic Species Sub-Goal: Iconic species are defined as those that are relevant to local cultural identity through one or more of the following: 1) traditional activities such as fishing, hunting or commerce; 2) local ethnic or religious practices; 3) existence value; and 4) locally-recognized aesthetic value[1]. Our efforts to define a list of iconic species specific to the Israeli Mediterranean resulted in a list of 77 species, mostly flagship species, a few species traditionally fished, and one gastropod which had been historically important for religious practices.

To assess the status of these iconic species within the region, we used the same methods used in the Species sub-goal for biodiversity in this assessment (see

Table 6 for categories and weights).

The IUCN species assessments were used for the calculation of the biodiversity goal because they cover a broad range of species chosen in a systematic way, regardless of conservation concern or charisma. These are more likely to be broadly representative of the status of unassessed species. The IUCN has only assessed the status of 51 of the iconic species (and the trend for only 36).

The status of the Species sub-goal (x_{SPP}) is measured as the weighted average of species extinction risk weights, such that:

$$x_{ICO} = \frac{\sum_{i=1}^{6} S_i * w_i}{\sum_{i=1}^{6} S_i} \quad \text{(Equation 10)}$$

where S_i is the number of species in each threat category i, and w_i is the risk status weights assigned to each of these categories. This formulation essentially gives partial credit to species that still exist but are vulnerable or imperiled. The target reference point here is that all species are assessed as “Secure”, giving a goal score of 1.

The trend was calculated as the average of the recorded categorical trend for all assessed iconic species, giving scores of 0.5 for increasing population, 0.0 for stable populations, and -0.5 for decreasing populations. Because all species are affected by pressures from human activities both on land and at sea, we assessed pressures based on all ecological pressure categories (except human pathogens), and all social pressures (except diesel gas price; see Table 11 for full list). All resilience measures were used, except climate change regulations (see Table 13 for full list).

Lasting Special Places Sub-Goal: As was done in the global assessment, the lasting special places sub-goal focuses on the conservation status of geographic locations that hold significant aesthetic, spiritual, cultural, recreational, or existence value for people. Measuring the status of this goal proved difficult, as places hold special value for people for a myriad of reasons, and personal associations with places are difficult to quantitatively assess. Ideally, one would have (or develop) a list of all the places that people within a study area consider special, and then assess what percentage of those areas are protected and how well they are protected.

For the local Israeli assessment, we covered three data sets of marine and coastal areas that suggest, according to efforts to protect them, that they are significant to people: Marine and coastal areas designated as marine protected areas (MPAs) by the Israel Nature and Parks Authority in order to comply with the Convention of Biodiversity’s target to conserve at least 10% of coastal and marine waters by 2020; declared archeological sites; and beaches of special public interest, which represent civilian struggle against shoreline development, (see Archeological Protected Areas, Beaches of Special Public Interest, and Marine Protected Areas specific Data Layers for more details).

Declared archeological sites are officially protected by law, but have been subject to devastation by trawling equipment. Antiquity sites and trawling lane mapping enabled categorizing the archeological sites in to two groups: those within trawling lanes (thus not protected) and those outside trawling lanes.

In Israel, building within 100 m of the shoreline has been prohibited by law since 2004. Beaches of special public interests are mostly coastal projects that had been authorized for development before 2004, and which have caused civil protest activities. The location of struggle over beaches and the measure of success in keeping those beaches wild was mapped by "Adam Teva V'Din" NGO[8], the Israel Union for Environmental Defense. The areal extent of these projects was assessed.

The status calculation is therefore:

$$x_{LSP} = \frac{\sum_k a_{p,k}}{\sum_k a_{s,k}} \quad , \qquad \text{(Equation. 11)}$$

where a_p is the fully- protected area in category k, within coastal waters of the region, a_s is the area suggested to be protected, k is the categories: MPAs, archeological sites and beaches of special public interest.

The trend is calculated based on the change in the total marine area protected (archeological site, MPA, and beaches of public interest) in each region from 2009 to 2013. See Table 11 for pressure details and Table 13 for resilience measures.

G. Clean Waters

People enjoy the presence of unpolluted estuarine, coastal, and marine waters for their aesthetic value and because they help avoid detrimental health effects to humans and wildlife. To calculate this goal, we measure the status of four different contributors to water pollution: nutrients, pathogens, chemicals, and trash. As was done in the global assessment, we focus on assessment of nearshore waters. Although clean waters are relevant and important anywhere in the ocean, coastal waters drive this goal. This is because the problems of pollution are concentrated there and because of potential mitigation efforts. In addition, people predominantly access and care about clean waters in coastal areas. Furthermore, we have severe data limitations for open ocean areas with respect to measures of pollution.

The status of this goal (x_{CW}) is calculated as the geometric mean of four components, such that:

$$x_{CW} = \sqrt[4]{a*u*l*d} \qquad \text{(Equation 12)}$$

where *a* = 1 – (pathogen score), *u* = 1 – (nutrient input score), *l* = 1 – (chemical input score), and *d* = 1 – (marine debris input score).

For the nutrients component, we used the nitrate pressure mapping (Herut et al., August 2011) versus a background level value of 0.6 micromolar (x). Present value of nutrients was then calculated as 1-*x*, where x is the zonal mean out to 10 km in each region. For the pathogens layer, we used the Ministry of Health's sea water enterococci numbers in sea water monitoring, and the formal categories: 0-35 bacteria in 100 ml (good), 36-104 (ok) and >104(bad). Good samples scored 0 pollution; OK scored 0.3; Bad scored 1. Beach-level data were aggregated to our regions. Present value of pathogens is then calculated as 1-x per region, where x is the average exceedance value for each region in 2013. For the trash layer, we used the "Clean Beach Index"[9] from the Israel Ministry of Environmental Protection. These data monitor the amount of plastic trash on beaches other than declared for swimming. We assumed that data represent all trash present on the beach. The official target for the "Clean Beach Index" is that 70% of the municipalities are clean/very clean 70 % of the time.

Our target reference point is that all of the beaches in each region are clean/very clean 70% of the time, thus conforming with the official targets to a great extent.

To calculate a score for the chemicals layer we used Israel Oceanographic and Limnological Research (IOLR) data, which consist of coastal fish tissue samples collected from Israeli coastal and estuarine regions from 2008-2012. The fish sampled were: *Lithognathus mormyrus, Diplodus cervinus, Mullus surmuletus, Sargocentron rubrum, Siganus rivulatus, Siganus luridus*. These samples have measured trace element concentrations along the Israeli shore in the following sites: Haifa, Haifa Bay, Michmoret, Jisr Az Zarka, Ashdod, Netanya, Palmachim, Accre. No samples have been collected from the Tel Aviv district, thus was assigned the pollution value of the encircling Center region. For the present value of chemicals, we focus on the heavy metals for which there are explicit threshold values[10]: arsenic, cadmium, lead, mercury. Although this is a subset of all chemical pollutants, these in-situ measurements are the most temporally and spatially available. We scored each sample categorically as follows, using specific threshold values for tissue samples from the Ministry of Health's guidelines on maximal concentrations. Above maximal guideline concentration: 0.0 (bad), and below 1.0 (good). (See Table 7 for Ministry of Health derived chemical threshold values). We aggregated the scores by computing the mean for each contaminant category, grouped by district and year.

Table 7: Ministry of Health Maximal Fish (excluding predatory open water fish) tissue Guideline threshold values. Samples above this threshold were given 0.0 score. Samples below these threshold values were given 1(maximal) score.

Contaminant	Israeli Ministry of Health Maximal Fish Tissue Guidelines ppm
Arsenic	1
Cadmium	0.05
Lead	0.3
Mercury	0.5

Status data for the nutrients layer come from the IOLR nitrate concentration monitoring in August, 2011[12] and from mapping of coastal waters. Nutrient trend data comes from IOLR estimates of nitrogen point source input into the marine environment during 2007–2011 (most recent data)[11–14]. The trend in pathogens data is calculated as the change in status scores from 2009–2013. Trend for the chemicals layer comes from the same IOLR categorical data, with trends calculated as the slope of a linear regression for values between 2008 and 2012 for each district. For the trash layer, the trend is calculated over the status scores from 2009–2013. See Table 11 for pressure details and Table 13 for resilience measures.

H. Tourism and Recreation

This goal captures the value people have for experiencing and taking pleasure in coastal areas. There are many ways to potentially measure the delivery of this goal. In the original global analysis[1], data on international arrivals were used as a proxy for the value of tourism and recreation in each region, as this was the most comprehensive data available on a global scale.

In this assessment, we use the amount of coastal park visits and hotel occupancies as a proxy for the number of people actually engaged in coastal tourism, assuming that the number of tourists in coastal parks is more indicative of a healthy ocean than coastal city hotel occupancies. A similar approach using employees in the hotel industry was done in the Brazil assessment[5]. Hotel data was available for the following coastal cities: Netanya, Herzlia, Tel Aviv, and Bat Yam.

Status for this goal is calculated using a weighted average of park visitation numbers and hotel occupancies with half the weight of "parks" given to "hotels" (i.e. 1/3 for hotels and 2/3 for parks. We regionalized the data for each district.

$$x_{TR} = TR_{Hotels} * S_i * \frac{1}{3} + TR_{Parks} * \frac{2}{3} \ , \qquad \text{(Equation 13)}$$

A sustainability index was applied to coastal city hotels, according to a 2013 evaluation by the World Travel and Tourism Council (WTTC)[14a].

Hotels reference points were taken from official planning targets for year 2020.

City	Targeted number of rooms for year 2020	Data source
Netanya	2466	National plan 13, Netanya correction (Tama13 correct)
Hertzlia	2692	Herzlia city plan (in prep.) Data interpolated assuming linear growth
Tel Aviv-Jaffa	7124	Tela aviv municipality policy doc
Bat Yam	1856	Bat Yam city plan (in prep.) Data interpolated assuming linear growth

"Hotels" status is the number of occupied beds divided by the official target and multiplied by tourism sustainability index.

$$TR_{Hotels} = \frac{\sum_{1}^{i} N_{i,} * O_i}{T_{i,2020}} \ , \qquad \text{(Equation 14)}$$

N_i is the number of rooms in district i,

O_i is hotel room occupancy percentage per district i,

$T_{i,\,2020}$ is the combined planning target of district i for year 2020.

"Parks" target is to achieve the highest number of tourists recorded in the time series, per park. Since the coastal parks are managed by the Israel Nature and Parks Authority, which is the governmental body charged with the protection of nature, landscape and heritage in Israel, we assume that tourism in these parks is managed sustainably.

$$TR_{Parks} = \frac{\sum_{1}^{N} \frac{V_j}{V_{j,\max}}}{N} \qquad \text{(Equation 15)}$$

N is the number of coastal parks in each district,

V_j is the number of visits in the current year j,

$V_{j,\,MAX}$ is the maximal visit number recorded per coastal park j.

The trend for tourism and recreation goal was calculated according to the slope of the status for the years 2009–2013.

See Table 11 for pressure details and Table 13 for resilience measures.

I. Coastal Livelihoods and Economies

This goal focuses on avoiding the loss of ocean-dependent livelihoods and productive coastal economies, while maximizing livelihood quality. We measure the status of this goal through two sub-goals: livelihoods (i.e., jobs and wages) and economies (i.e., revenues). Each goal is measured using sector-specific data from the Israel Central Bureau of Statistics. Sectors include coastal hotel jobs and animal agriculture (as a proxy for mariculture and fishing). For each of these sub-components, we used sector-specific multipliers data as in the Global OHI in order to assess both direct and indirect effects.

Livelihood Sub-Goal: As was done in the global analysis, coastal livelihoods is measured by two equally weighted sub-components, the number of jobs (*j*), which is a proxy for livelihood quantity, and the per capita average annual wages (*g*), which is a proxy for job quality. For both jobs and livelihood we used a no-net loss reference point. Therefore, the number of jobs is calculated by summing the total value in each *k* sector across all *n* sectors in the current year, *c,* relative to the value in a recent moving reference period, *r*, defined as five years prior to *c*, and average annual wages as the total value across all *n* sectors in the current year relative to the value five years prior to *c*, such that:

$$x_{LIV} = \frac{j' + g'}{2} \quad \text{(Equation 16)}$$

$$j' = \frac{\left(\dfrac{\sum_{k=1}^{n} j_{c,k}}{\sum_{k=1}^{n} j_{r,k}} \right)}{\dfrac{M_c}{M_r}} \quad \text{(Equation 17)}$$

where M is the overall employment rate as a percent (M = 100-unemployment) at current (c) and reference (r) time periods, and:

$$g' = \frac{\left(\dfrac{\bar{g}_{c,k}}{\bar{g}_{r,k}} \right)}{\dfrac{W_c}{W_r}} \quad \text{(Equation 18)}$$

where W is the average annual per capita wage at current (c) and reference (r) time periods.

The current year for agriculture of farmed animals was 2011, whereas tourism was 2013. The reference year for agriculture was 2007, and tourism 2009.

Economies Sub-Goal: The Coastal Economies sub-goal is composed of a single component, revenue (*e*), measured in NIS. As was done for the Livelihood sub-goal, status is based on a no-net loss reference point. Therefore, status is calculated as revenue from each k sector in the current year, *c,* relative to revenue from a recent moving reference period, *r*, defined as five years prior to *c*, such that:

$$x_{ECO} = \frac{\sum_{k=1}^{n} \frac{e_{c,k}}{e_{r,k}}}{\frac{E_c}{E_r}} \qquad \text{(Equation 19)}$$

where E is the annual total GDP at current (c) and reference (r) time periods.

As noted, jobs were adjusted by the overall State-level employment, wages were adjusted by the State's average annual per capita wages, and revenue was adjusted by the State's GDP. Absolute values for jobs and revenue were summed across regions and sectors, and absolute values for wages were averaged for both current and reference periods before calculating relative values per region. For status, we used 2011 as the current year for agriculture of farmed animals, whereas we used 2013 as the current year for tourism. The reference year for agriculture was 2006, and tourism 2008.

Trend was calculated as the percentage change in score from the current year to the reference year using a linear model across the individual sector values (aggregated across districts, but not sectors) for the adjusted jobs, wages and revenues. We then calculated the average trend for jobs and wages across all sectors, weighted by the number of jobs in each sector in the current year, and the average trend for revenue across all sectors, weighted by the revenue in each sector in the reference year. We averaged the wages and jobs slopes to get a trend value for coastal livelihoods, and used the weighted average slope in revenue for coastal economies. We included different pressures and resilience measures for each sector (see Tables 11 and 13 for a full breakdown of how these measures were applied). To calculate ecological pressures, we took the average weight across all sectors for each pressure, and for social pressures, we applied all measures included in the matrix evenly. Only the social resilience measures were used in the overall resilience score.

J. Natural Products

The collection and trade in natural resources, such as aquarium fishes and corals are prohibited by law in Israel. However, Israel relies heavily on sea water to provide drinking water for over half the households, by way of desalination. Therefore, the desalination of sea water was incorporated into the index as the Natural Products goal.

Producing the required amount of desalinated water sustainably was set out as the objective of natural products. Therefore, the status of natural products is calculated as

$$x_{NP} = \frac{Y_{Des}}{T_{Des,2020}} * S_{Des}, \qquad \text{(Equation 20)}$$

While Y_{DES} is the yield of desalinated water,
$T_{Des,\ 2020}$ is the target set by the Israel Water Authority for year 2020[15],
S_{Des} is a desalination sustainability index, developed specifically for the use in this local assessment.

Studies on the effect of desalination on the environment show a different reaction of each habitat to desalination effluents, much depending on local environmental conditions[16]. However, there is an increasing body of evidence, worldwide, showing the effect on the benthic ecology[17],[18].

In Hadera and Ashqelon, where desalination effluents are discharged, combined with power plant cooling water, there is evidence of "very poor benthic fauna" in the vicinity of the cooling water streams, an area of 500m along the shore by 250m, according to monitoring reports. In Palmachim, where the desalination brine is discharged without cooling water, monitoring reports have claimed a reduction in the numbers of fauna at the outlet alone.

The sustainability of desalination is a subject very little studied. We developed an index to assess the sustainability of desalination in Israel, based on reported measurements of the effect of the brine plume on the benthos, according to salinity monitoring data in relation to receiving habitats and their sensitivity. (See "

Desalination brine pollution

Where used: Used with other data layers in a variety of dimensions for all goals.
Scale: Regional scale.
Description: Studies on the effect of desalination on the environment show a different reaction of each habitat to desalination effluents, much depending on local environmental conditions16. However, there is an increasing body of evidence showing the effect on the benthic ecology17,18, especially on seagrass meadows.

In Hadera and Ashqelon, where desalination effluents are discharged combined with power plant cooling water, there is evidence of lower species richness in the vicinity of the cooling water streams. It is not clear what causes the decline in species richness according to the authors of the monitoring reports, if the rise in temperature, salinity, a normal variation or other factors. In Hadera, an area of 500m along the shore by 250m, next to the outlet where salinity ranges between 41.1 and 42.95 PSU is characterized by "very poor benthic fauna" according to monitoring reports23. In Palmachim, the desalination brine is diffused without power plant cooling water. Three years prior to the activation of the desalination plant, a seagrass meadow was recorded at the outlet site23a. It was not sighted in subsequent sampling that year, and has not been sighted since. Monitoring reports produced after the activation claim a reduction in the numbers of fauna at the outlet alone.

A spatial assessment of the desalination plume brine was carried out in order to assess the magnitude of the possible pressure on the benthic ecosystems in the Israeli EEZ and territorial waters, assuming rise in salinity above a certain threshold would detrimentally affect the benthic communities.

Monitoring data was received from the three desalination companies Via Maris, VID and H2ID, operating at Palmachim, Ashqelon, and Hadera.

Bottom depth measurements were retrieved from the data bases. Background salinity values per each sampling date was determined according to the lowest measurements between the two reference-stations present in each monitoring data set.

The deviations from the background salinity was measured for Palmachim, Ashqelon, and Hadera for the sampling points closest to the sea bottom. Maximal deviation from background values for each sampling point were charted. These values were log (x+1) transformed to range between zero to one, using background levels as zero and measurements above 41.1 psu as one. A spatial mean for the EEZ of the values indicated the pressure for each region. A caveat of this method is that the area monitored typically did not cover the entire plume of brine, and we assessed all the area outside the monitoring zone as zero pollution. New monitoring protocol in Palmachim, will hopefully enable a better future assessment of the scope of the brine plum.

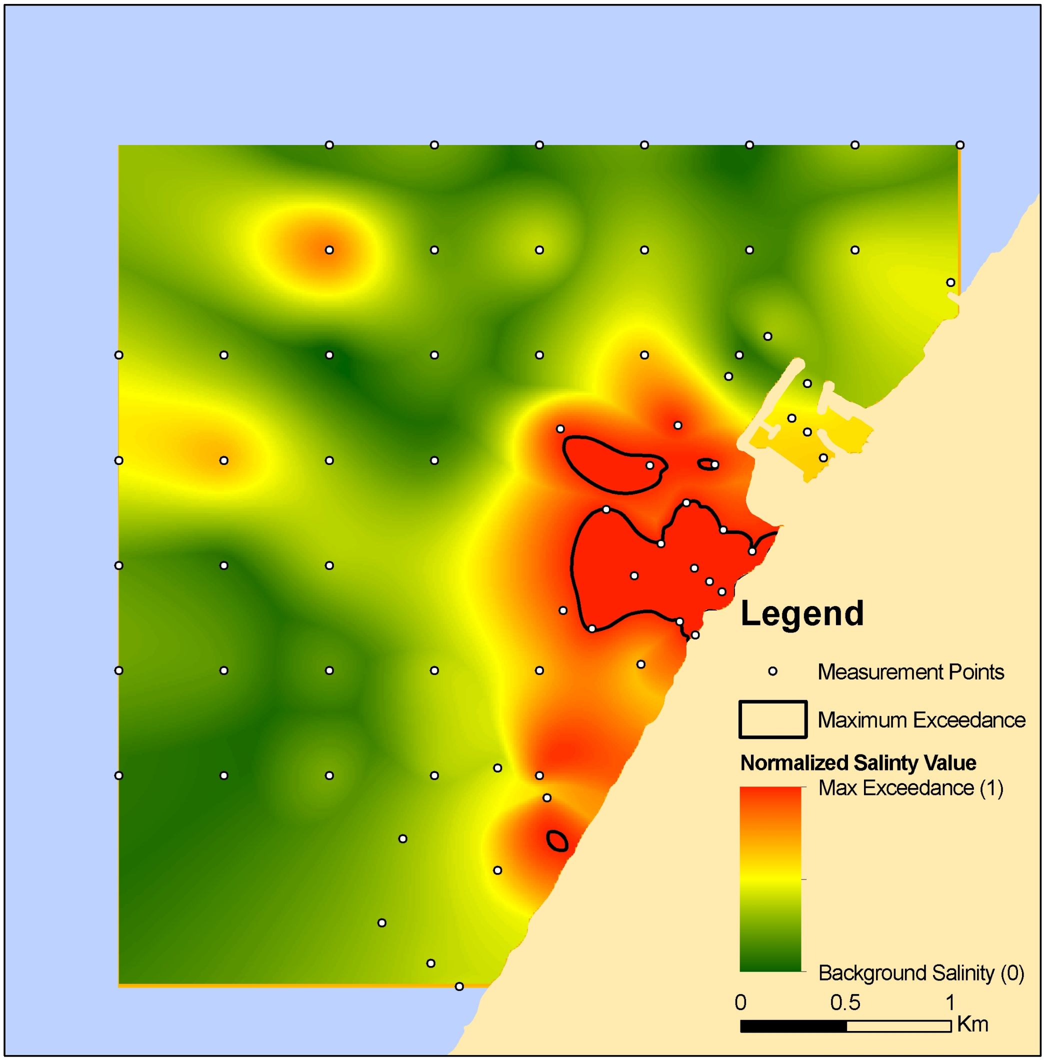

Figure 2: Ashqelon desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth in the data series of 2005-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and VID Desalination Company.

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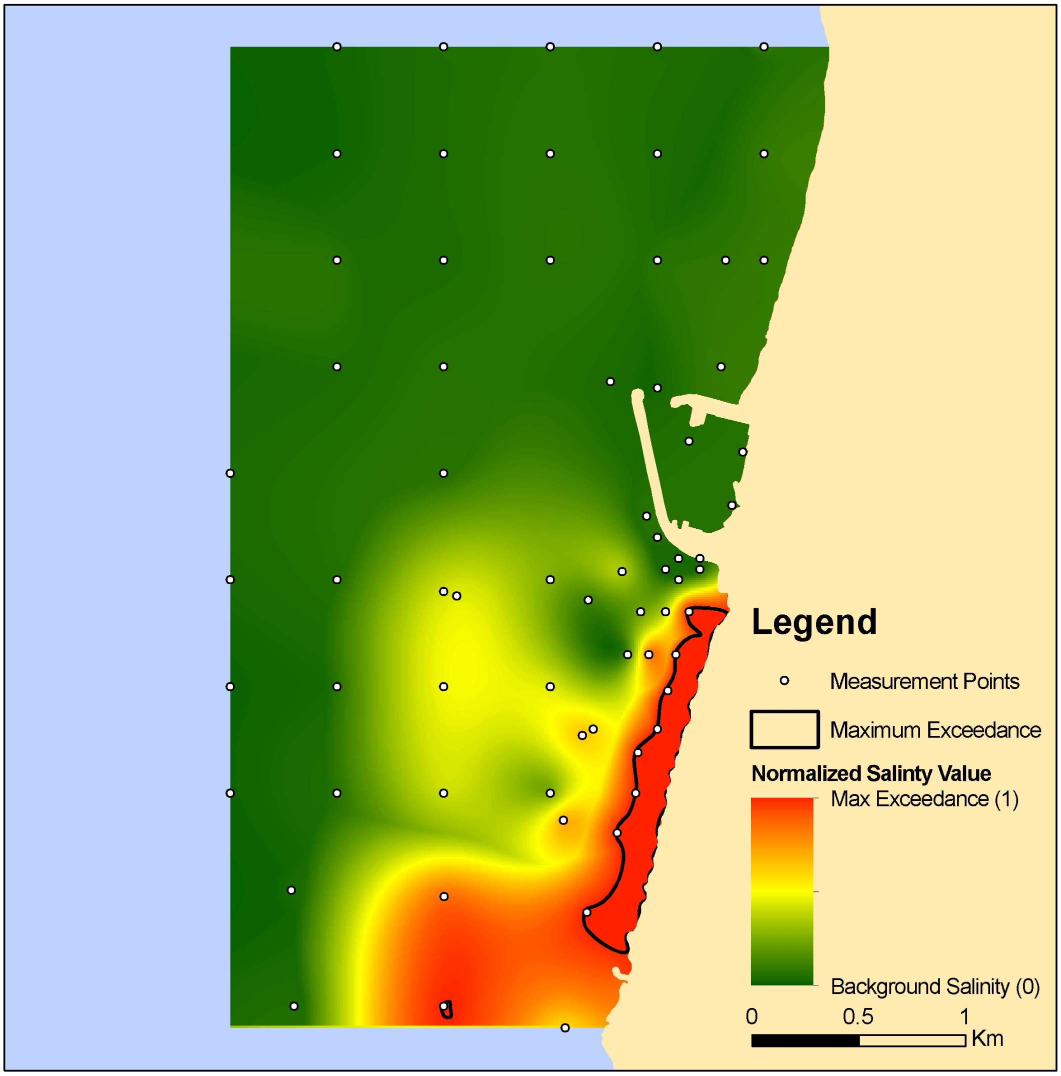

Figure 3: Hadera desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth, in the data series of years 2009-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and H2ID Desalination Company.

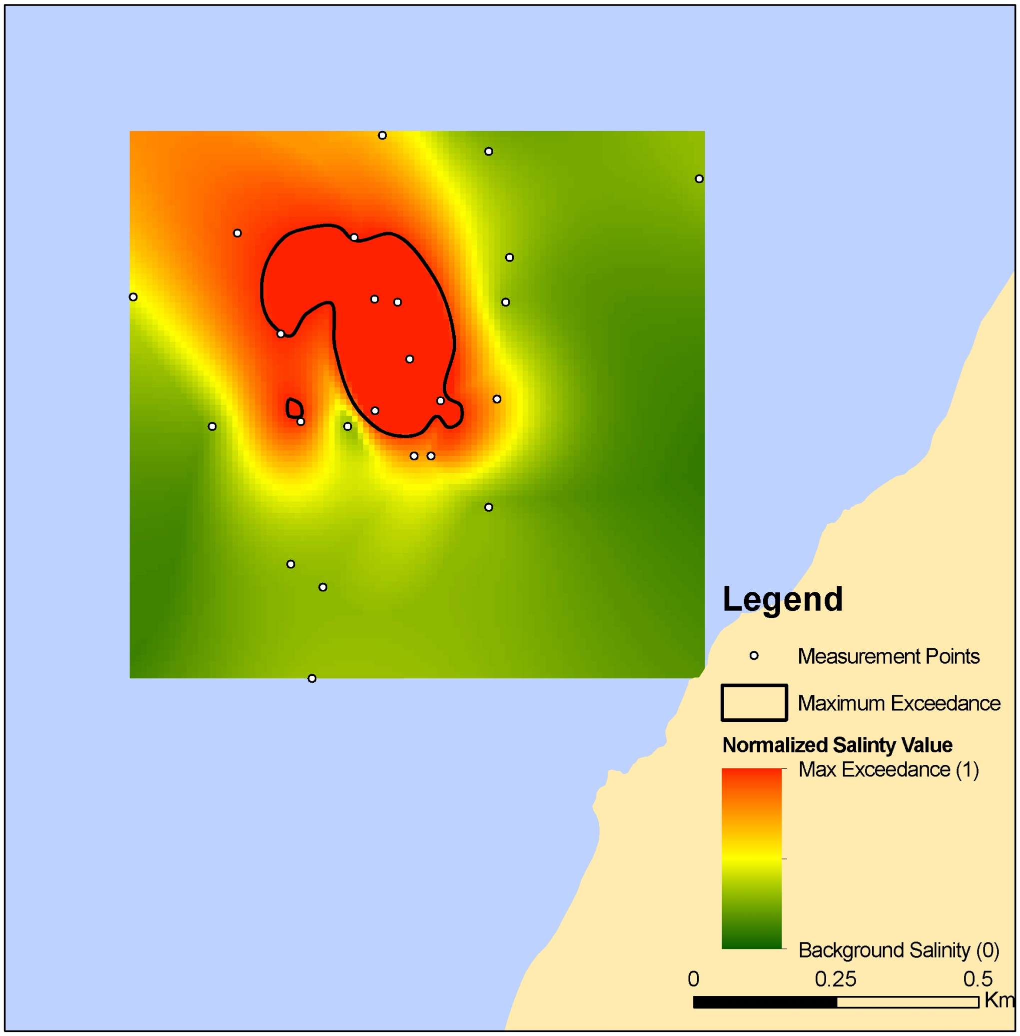

Figure 4 Palmachim desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth in the data series for years 2009-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and Via Maris Desalination Company.

Desalination Sustainability Index" specific data layer for more information). The desalination sustainability's value is a number close to 1, and has near to no effect on the score of the Natural Products goal.

We included different pressures and resilience measures for this goal (see Tables 11 and 13 for a full breakdown of how these measures were applied).

Specific Data Layers

Data layers that are new to this assessment are listed in this section.

Alien Invasive Species

Where used: Pressure for many goals.

Scale: Mediterranean and Black Seas analysis [19].

Description: These data come from the Mediterranean and Black Sea analysis[19]. The mapped pressures were transformed to the New Israeli Grid clipped to the Israeli waters and regions, and rescaled from 0 to 1 (log (x+1)) according to the maximal pressure in the entire Mediterranean and Black Sea data. See Reference[19] for further information.

Archeological Protected Areas

Where used: Status and trend for Lasting Special Places sub-goal.

Scale: Archeological site specific data.

Description: Once an archeological site is discovered by the Israel Antiquities Authority, it is declared and protected by law. Trawl fishermen are not prevented from trawling in areas declared as archeological sites, and thus damage the sites. This is a worldwide problem[20–22]. A GIS mapping of all declared antiquity sites was provided by the Antiquities Authority. The extent of the mapping used for this assessment includes all marine sites (marked as quadrates), as well as sites within the coastal environment: 300m inland, each quadrate with the year the area was declared an archeological site. A qualitative trawling lane mapping[3] enabled categorization of the archeological sites into two groups: those within trawling lanes (thus not protected) and those outside trawling lanes (protected).

Beaches of Special Public Interest

Where used: Status and trend for Lasting Special Places sub-goal.

Scale: Beach scale.

Description: In 2004 the "Protection of the Coastal Environment Law "_was passed in Israel. This law states that beaches are public owned, and building within 100 m of the coastline is prohibited. Projects that were authorized before 2004 have caused public disputes over their development. A log of all coastal disputes has been received from "Adam Teva V'din" NGO, with initiation dates and a qualitative description of the success in keeping the beach public (Successful=1, mostly successful= 0.75, partialy successful=0.5, failure=0). A spatial assessment of the size of beach disputed was assigned for each project: from 50 m (beach shop) to 2000m (marina), with a 100 m inland buffer area.

(Success *area disputed)/area disputed gave the measure of maintaining special beaches.

Climate Change: pH

Where used: Pressure for several goals.

Scale: Mediterranean and Black Sea analysis[19].

Description: These data come from the Mediterranean and Black Sea analysis[19]. The mapped pressures were transformed to the New Israeli Grid, clipped to the Israeli waters, and rescaled from 0 to 1 (log (x+1)) according to the maximal pressure in the entire Mediterranean and Black Sea data. See Reference[19] for further information.

Climate Change: Sea Surface Temperature (SST) Anomalies

Where used: Pressure for several goals.

Scale: Mediterranean and Black seas analysis[19].

Description: These data come from the Mediterranean and Black Sea analysis[19]. The mapped pressures were transformed to the New Israeli Grid, clipped to the Israeli waters, and rescaled from 0 to 1 (log (x+1)) according to the maximal pressure in the entire Mediterranean and Black Sea data. See Refrence[19] for further information.

Climate Change: UV

Where used: Pressure for several goals.

Scale: Mediterranean and Black seas analysis [19].

Description: These data come from the Mediterranean and Black Seas analysis[19]. The mapped pressures were transformed to the New Israeli Grid, clipped to the Israeli waters, and rescaled from 0 to 1 (log (x+1)) according to the maximal pressure in the entire Mediterranean and Black Sea data. See Reference[19] for further information.

Coastal Regions

Where used: Used with other data layers in a variety of dimensions for all goals.

Scale: Regional scale.

Description: We sub-divided the Israeli Mediterranean coast into six coastal regions based on a combination of administrative (i.e. district) boundaries and Haifa Bay, a distinct biogeographic province. To produce the spatial boundaries of these reporting units (i.e., the GIS spatial files associated with them), we first extracted the district mapping from the Ministry of Interior data base, and extended the coastal district division lines to the Israeli Exclusive Economic Zone (EEZ) extent. To compensate for the concave coastline and the divergence of the extended lines, we adjusted the boundary between the two northernmost regions so that they were parallel with the EEZ boundary, so as to preserve a roughly similar ratio between the regions and their land surface area.

Coastal Parks: Visit Numbers

Where used: Status and trend for tourism and recreation goal.

Scale: Park scale.

Description: Recreation participation data come from the Central Bureau of Statistics. The data included the number of visits in all national parks. We selected the parks that are coastal: Dor-Habonim, Achziv, Apollonia, Caesarea, Beit Yannai, and Ashqelon. The maximal number of visits in the time series (2003-2012) of each park was set as the reference point for the specific park. Palmachim Park was not included, since its data series was insufficient (2011-2012).

Coastal Population

Where used: Used with other data layers in a variety of dimensions for all goals.
Scale: Regional scale.
Description: The data come from the Israeli Central Bureau of Statistics data for 2013.

Coastline and Coastal Zone Area

Where used: Used with other data layers in a variety of dimensions for all goals.
Scale: Regional scale.
Description: We extracted a high-resolution land-sea interface (i.e., coastline) based on a 25 cm orthorectified aerial imagery (Survey of Israel 2012), and then computed an offshore 3 nmi and 12 nmi boundary per district for use with some goals, a 100 m inland buffer for the shoreline area, and a 300 m inland buffer for the coastal zone.

Desalination brine pollution

Where used: Used with other data layers in a variety of dimensions for all goals.
Scale: Regional scale.
Description: Studies on the effect of desalination on the environment show a different reaction of each habitat to desalination effluents, much depending on local environmental conditions[16]. However, there is an increasing body of evidence showing the effect on the benthic ecology[17],[18], especially on seagrass meadows.

In Hadera and Ashqelon, where desalination effluents are discharged combined with power plant cooling water, there is evidence of lower species richness in the vicinity of the cooling water streams. It is not clear what causes the decline in species richness according to the authors of the monitoring reports, if the rise in temperature, salinity, a normal variation or other factors. In Hadera, an area of 500m along the shore by 250m, next to the outlet where salinity ranges between 41.1 and 42.95 PSU is characterized by "very poor benthic fauna" according to monitoring reports[23]. In Palmachim, the desalination brine is diffused without power plant cooling water. Three years prior to the activation of the desalination plant, a seagrass meadow was recorded at the outlet site[23a]. It was not sighted in subsequent sampling that year, and has not been sighted since. Monitoring reports produced after the activation claim a reduction in the numbers of fauna at the outlet alone.

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The deviations from the background salinity was measured for Palmachim, Ashqelon, and Hadera for the sampling points closest to the sea bottom. Maximal deviation from background values for each sampling point were charted. These values were log (x+1) transformed to range between zero to one, using background levels as zero and measurements above 41.1 psu as one. A spatial mean for the EEZ of the values indicated the pressure for each region. A caveat of this method is that the area monitored typically did not cover the entire plume of brine, and we assessed all the area outside the monitoring zone as zero pollution. New monitoring protocol in Palmachim, will hopefully enable a better future assessment of the scope of the brine plum.

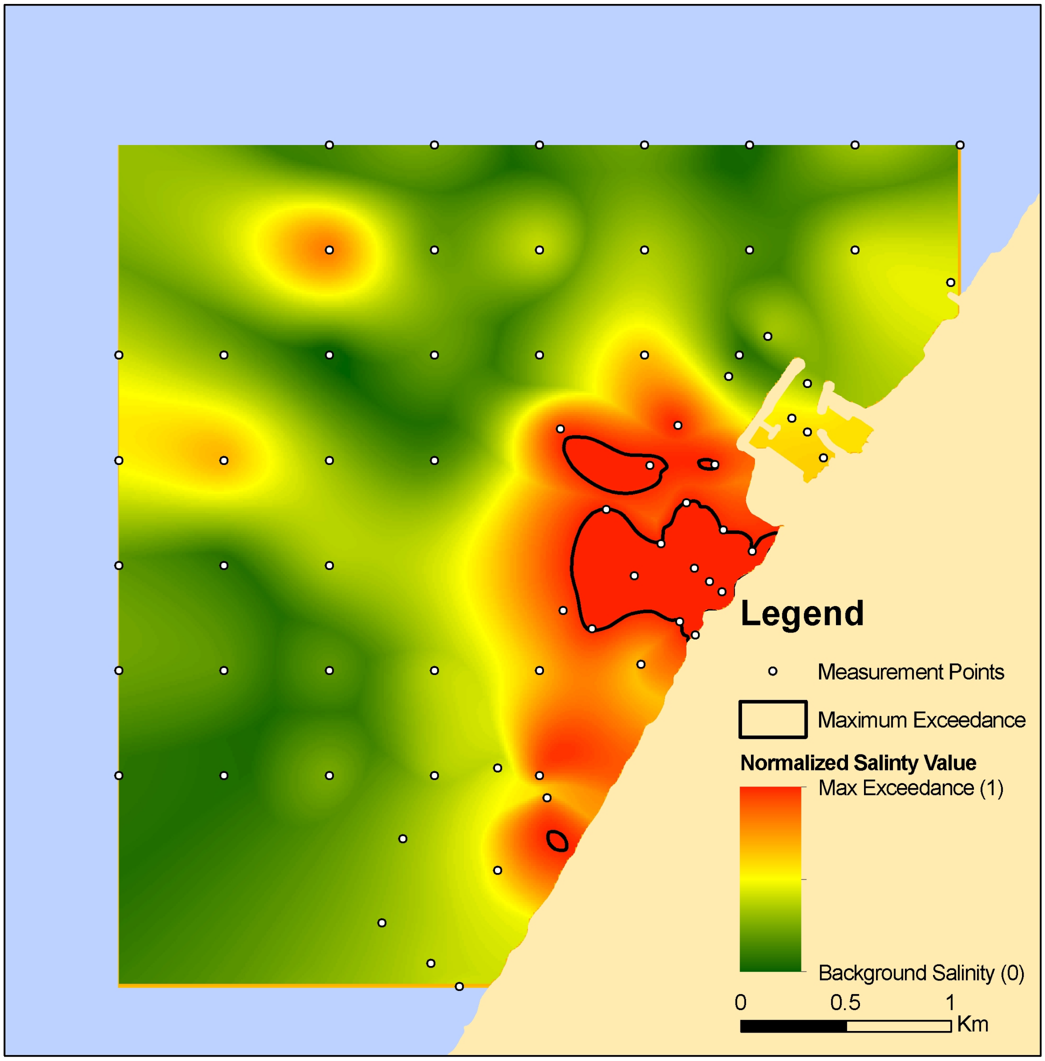

Figure 2: Ashqelon desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth in the data series of 2005-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and VID Desalination Company.

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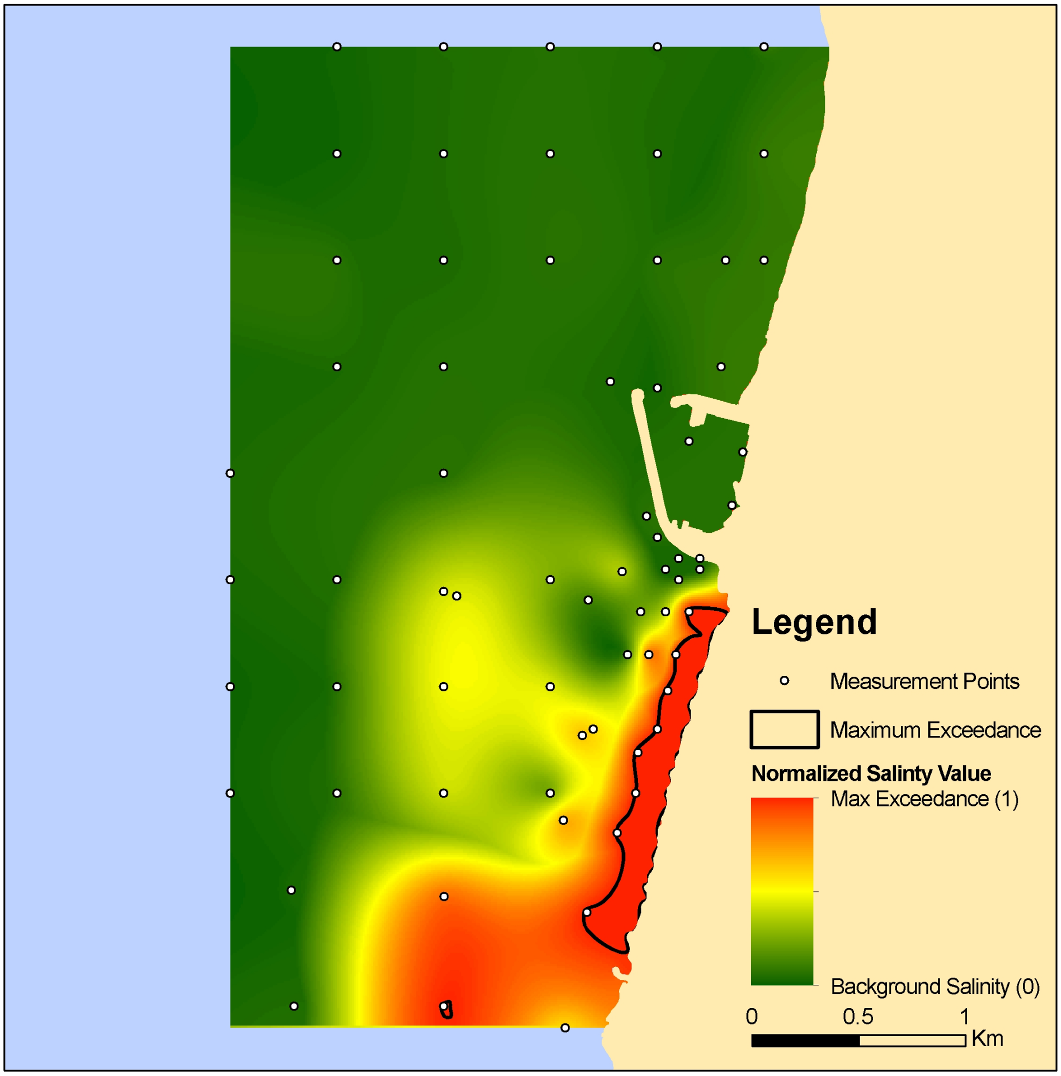

Figure 3: Hadera desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth, in the data series of years 2009-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and H2ID Desalination Company.

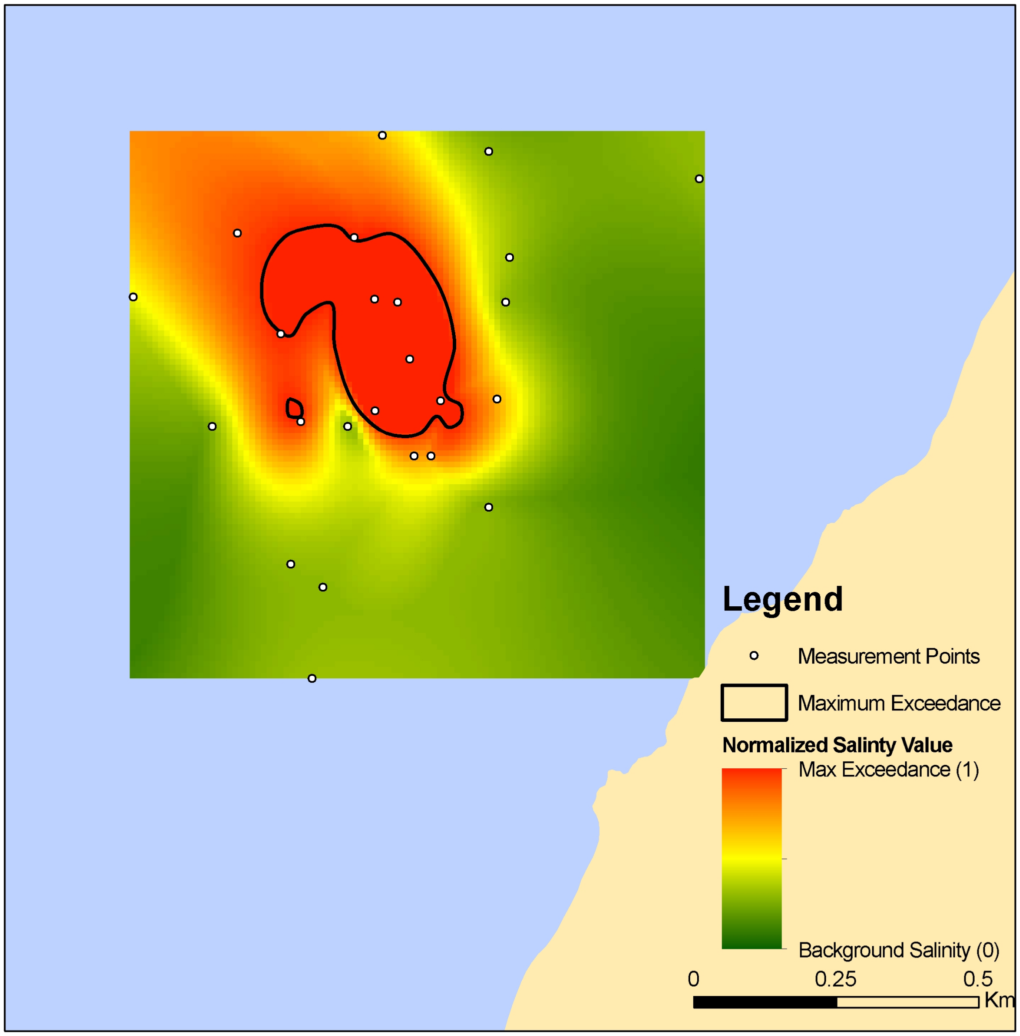

Figure 4 Palmachim desalination brine pollution assessment. Maximal Salinity exceedance from background values measured at bottom depth in the data series for years 2009-2014. Values normalized between zero and one, and spline interpolated. Data courtesy of Israel Electric Corporation and Via Maris Desalination Company.

Desalination Sustainability Index

Where used: Natural products Status and Trend calculations.

Scale: Regional scale.

Description: The sustainability of desalination was assessed according to habitat mapping and sensitivity assessment done by the Israel Nature and Parks Authority[24] and according to spatial monitoring of the desalination brine done by desalination companies Via Maris, VID and H2ID. (1- average brine pressure) above soft-bottom habitats sustainability was multiplied by a value of 0.9 (in the range of 0 to 1); over a rocky habitat it was multiplied by 0.1 due to the high diversity and sensitivity of this habitat[24–26]. The Desalination Sustainability Index was calculated as the spatial mean of this value for each region. A caveat of this method is that the area monitored typically did not cover the entire plume of concentrate; hence, we assessed all the area outside the monitoring zone as sustainable.

Heavy Metal Threshold Values (Israeli Ministry of Health Guidelines)

Where used: Status and trend for clean waters goal, pressure for many goals.
Scale: Coastal waters.
Description: The Israeli Ministry of Health establishes action levels for poisonous or deleterious substances in food that represent limits at or above which the Israeli Ministry of Health will take legal action to remove food products from the market. The levels for four heavy metals monitored by IOLR[10] are used to establish "bad" and "OK" criteria, according to the Israeli Ministry of Health threshold for heavy metal concentrations in fish (excluding predatory open-water fish). These results are used to score the chemicals component of the Clean Waters goal.

Table 8: Ministry of Health Maximal Fish (excluding predatory open-water fish) tissue guideline threshold values.

Contaminant	Israeli Ministry of Health Maximal Fish Tissue Guidelines ppt
Arsenic	1
Cadmium	0.05
Lead	0.3
Mercury	0.5

Samples above this threshold were given a 0.0 score. Samples below these threshold values were given a 1 (maximal) score.

Hotel Bed Numbers and Occupancy

Where used: Status and trend for tourism and recreation goal.
Scale: Regional scale.
Description: Coastal city hotel bed numbers and occupancy percentages were retrieved from the Israeli Central Bureau of Statistics for the cities Netanya, Herzlia, Tel Aviv, and Bat Yam. These cities are generally outside conflict areas, and were selected by the Israel Ministry of Tourism to represent coastal tourism.

Fisheries Catch Totals

Where used: Status and trend for Fisheries sub-goal, aggregation of sub-goals for food provision score.
Scale: Country scale.

Description: Data for wild-caught fish harvest weight by species, and other taxa in the Israeli waters come from Edelist (2012)[3]. For the Fisheries sub-goal, the mean catch over the time series for each species was used to weight the contribution of each B/B_{MSY} and F/F_{MSY} derived score to the overall sub-goal score. The sum of all catches across species in 2012 was used when combining the two sub-goals (mariculture and fisheries) to weight the contribution of wild-caught fisheries to the overall food provision goal score.

GDP

Where used: Status and trend for Economies sub-goal.
Scale: Country scale.
Description: GDP values come from the World Bank website: http://data.worldbank.org/country/israel
We then adjusted these dollar estimates for inflation, and all values are given in 2010 dollars.

Genetic Escapes

Removed From This Assessment
Scale: Country scale.
Description: This layer was removed due to the fact that the mariculture industry grows local fish which seem to be genetically indistinct from wild populations[26].

Habitat Destruction, Intertidal Trampling

Where used: Pressure for several goals.
Scale: Regional scale.
Description: The Global 2012[1] model for this pressure was updated with 2013 population density mapping from the Israeli Central Bureau of Statistics.

Habitat Destruction, Sub-tidal Soft-Bottom

Where used: Pressure for many goals, status for soft-bottom habitats in the biodiversity goal.
Scale: Country scale.
Description: We used bottom-trawling pressure on soft-bottom habitats as a proxy for overall soft-bottom habitat (within the trawling grounds) pressures. Trawling routes were taken from Edelist (2012)[3], and trawling grounds were defined thereafter. Time series of the number of trawling days per year were received from the Department of Fisheries at the Israel Ministry of Agriculture, (t_y for 1950-2010). Trawl removal rate (*rr*) of 15.5% was taken from Moran & Stephenson (2000) [27]. Average width of disturbed soft-bottom habitat, according to active trawler boats, was taken as 50m (*w*), while the typical distance trawled during a trawling day is normally 150 km (*d*) (Edelist, pers. comm.) A rehabilitation time of three years was assumed for this model, since there are normally

no biogenic structures present in this soft-bottom habitat [28,29]. The pressure on the soft-bottom habitat was assessed by the fraction of the trawling ground trawled each year (tf_Y, equation 23), the removal rate (rr), and the rehabilitation rate (decay rate), with a target reference point of zero trawling in any area, assuming a log removal of biota with each trawl and log rehabilitation rate.

$$HD_{sb} = \sum_{y}^{y-3} tp \qquad \text{(Equation 21)}$$

$$tp_y = 1 - (1 - rr * Decayrate_y)^{tf_y} \qquad \text{(Equation 22)}$$

$$tf_Y = \frac{d * w * t_y}{a_{trawl}} \qquad \text{(Equation 23)}$$

Decay rate was set at 0 in year *y*, 0.22 in year *y*+1, 0.0482 in year *y*+2, and 0.0106 in year *y*+3.

Iconic Species

Where used: Status and trend for Iconic Species sub-goal.
Scale: Regional scale.
Description: The list of iconic species (see Table 9) was developed by regional experts both internal and external to the project. An exhaustive list of potential species that could be considered of high aesthetic value, as well as species associated with traditional activities, such as fishing, or of local religious significance to the people of Israel was developed and then narrowed based on data availability from IUCN database. Details for the status and trend of these species are described below in the IUCN data layer description. These species are mostly flagship species.

Table 9: List of regional iconic (mostly flagship) species

Species *(scientific name)*	**Species *(scientific name)***	**Species *(scientific name)***
Squalus acanthias	*Hippocampus*	*Serranus hepatus*
Epinephelus aeneus	*hippocampus*	*Etmopterus spinax*
Gymnura altavela	*Scyllarides latus*	*Scyliorhinus stellaris*
Myliobatis aquila	*Carcharhinus limbatus*	*Torpedo torpedo*
Mustelus asterias	*Physeter macrocephalus*	*Tursiops truncatus*
Raja asterias	*Epinephelus malabaricus*	*Himantura uarnak*
Squalus blainvillei	*Rhinoptera marginata*	*Raja undulata*
Pteromylaeus bovinus	*Epinephelus marginatus*	*Centrophorus uyato*

Steno bredanensis	*Torpedo marmorata*	*Alopias vulpinus*
Carcharhinus brevipinna	*Cetorhinus maximus*	*Sphyrna zygaena*
Serranus cabrilla	*Carcharhinus melanopterus*	
Scyliorhinus canicula	*Galeus melastomus*	
Epinephelus caninus	*Raja miraletus*	
Carcharodon carcharias	*Mobula mobular*	
Caretta caretta	*Monachus monachus*	
Ziphius cavirostris	*Chimaera monstrosa*	
Oxynotus centrina	*Raja montagui*	
Dasyatis centroura	*Mustelus mustelus*	
Dasyatis chrysonota	*Chelonia mydas*	
Raja clavata	*Torpedo nobiliana*	
Stenella coeruleoalba	*Carcharhinus obscurus*	
Epinephelus coioides	*Squatina oculata*	
Dermochelys coriacea	*Isurus oxyrinchus*	
Epinephelus costae	*Dasyatis pastinaca*	
Pseudorca crassidens	*Pristis pectinata*	
Ocypode cursor	*Heptranchias perlo*	
Delphinus delphis	*Balaenoptera physalus*	
Odontaspis ferox	*Carcharhinus plumbeus*	
Hippocampus fuscus	*Mustelus punctulatus*	
Galeorhinus galeus	*Raja radula*	
Prionace glauca	*Hippocampus ramulosus*	
Taeniura grabata	*Rhinobatos rhinobatos*	
Grampus griseus	*Mycteroperca rubra*	
Epinephelus haifensis	*Serranus scriba*	

IOLR Heavy Metal Concentrations in Coastal Fish Data

Where used: Status and trend for clean waters goal.
Scale: Coastal water regional scale.
Description: IOLR heavy metal concentration data come from marine fish tissue samples collected from Israeli coastal waters during 2007-2011 In the following coastal fishes *Lithognathus mormyrus, Diplodus cervinus, Mullus surmuletus, Sargocentron rubrum, Siganus rivulatus, Siganus luridus* (Herut et al., 2008 -2012)[11-14]. These specimens were collected along the Israeli shore in the following sites: Haifa, Haifa Bay, Michmoret, Jisr Az Zarka, Ashdod, Netanya, Palmachim, Accre. No samples have been collected from the Tel Aviv district, therefore, Tel aviv Region was assigned the pollution value of the encircling Center Region. Our analysis filters these data to include only the fish tissue. We analyzed heavy metal (As, Cd, Pb, Hg) concentrations based on the thresholds for fish tissue samples, then assigned a numerical score to each sample categorically — 0.0 (bad), and 1.0 (good). Missing data were interpolated according to the methodology in Halpern et al.,2012[1] (supplementary information).We aggregated the

scores by computing the mean for each contaminant category, grouped by region and year. See Table 8 for threshold values.

Mariculture Sustainability Index (MSI) Scores

Where used: Status and trend for Mariculture sub-goal, Fisheries goal.
Scale: Country scale data.
Description: The finfish *Sparus* aurata is almost the only species cultured at sea. The sustainability score (S_i) for *Sparus aurata* (0.56) comes from the Mariculture Sustainability Index (MSI)[30] and is the average of three sub-indicators used in the MSI: wastewater treatment, the origin of feed, and the origin of seed. The three specific sub-indicators were chosen because they reflect the long-term sustainability of the mariculture practice, but are not reflective of the impacts the mariculture practices may have on the surrounding environment or species, as such impacts would not hinder the future production and sustainability of the Mariculture sub-goal itself even though they might affect the delivery of benefits from other goals. See Table 10 for the sustainability score (S_i) applied to the finfish species harvested in Israel.

Table 10: Sustainability score (S_i) for Sparus aurata

Indicators	*Sparus aurata*	Indicator score
Source of seed	Commercial farming	100/100
Fish feed and fish oil contents	Maximal content 43%	(100-43) /100
Waste water treatment	None- cage farming	10/100
S_i score	**Average**	**56/100**

Mariculture Yield

Where used: Status and trend for Mariculture and Fisheries sub-goals.
Scale: Country scale data.
Description: Values for the yield of finfish species grown in Israel between 2008-2013 come from data compiled by the Unit of Fishery and Mariculture at the Ministry of Agriculture. Data are given in tons of fish produced by cage farming overall in the Israeli Mediterranean per year.

Marine Jobs, Wages, and Revenue

Where used: Status and trend for livelihoods and economies goal.
Scale: Country scale data.
Description: These data come from the Israeli Central Bureau of Statistics. Data are currently available for 2006-2012 for two economy sectors: tourism and farmed animal culture. These sectors are not marine, and are used as proxies. For our analysis, we

used the wage and salary employment (jobs), average wages (wages), and GDP (revenue) data.

Marine Protected Areas

Where used: Status and trend for Lasting Special Places sub-goal, resilience measure for many goals.

Scale: Marine Protected Area (MPA) specific data.

Description: MPA information comes from 2013 mapping of MPAs by the Israel Nature and Parks Protection Authority. This geospatial database contains information on year of designation and protection status. These data were used to determine the total area covered by marine protected areas within two regions: coastal waters (0-12 nmi buffer for each region) and onshore (100 m inland). When used for the lasting special places goal, these two buffers were combined. When used for resilience measures, a single score for the entire region (coastal and EEZ) was used.

Marine Species

Where used: Status and trend for Species sub-goal of biodiversity goal; ecological integrity resilience measure for several goals.

Scale: Mediterranean and Black Sea analysis.

Description: For status and trend, marine species listed within the IUCN Red List are used for the Israeli Mediterranean marine species list. A list of species was composed, based on Galil et al.,[6] and updated with data for marine mammals (IMMRAC data center), Chondrichthyes (Barash, pers. comm.), and marine turtles[7]. This list, comprising 762 species (Appendix 1), was crossed with IUCN Global Marine Species Assessment. Assessments for all species for which distribution maps were available (from a global 0.5° grid) were retrieved. For those species prevalent in the region and that were not included in the distribution maps, the assessment was set according to the Mediterranean and Black Sea assessment data. Additional data gap filling was done according to global assessment data. This resulted in a listing of 249 IUCN species, with status data for 206 of them. Though this is a very small sub-sample of the actual marine species present in the range, it represents the most comprehensive species status dataset available for the region and is used as a proxy of overall species status in the area. The list of Israeli species, and their conservation status, trend and last assessment year, are presented in Appendix 1.

Nutrients Mapping

Where used: Status for clean waters goal, pressure for many goals.

Scale: Coastal waters data.

Description: The IOLR nitrate map (Aug, 2011) out to 10 km was used to proxy nutrient status. The concentration maps were georeferenced by extraction of the contour lines to a vector layer, followed by interpolation (using the Topo to Raster tool) of layer to a

100m resolution raster. The mean concentrations per district were compared to a background reference value of 0.6 micromolar (Suari, pers. Comm.). The pressure measure is calculated as 1 – the status score, or simply x.

Nutrient Input of Point Sources

Where used: Trend for clean waters goal.

Scale: Regional data.

Description: The trend is calculated as the change in annual nitrogen input from point sources[10], aggregated per district over the last five years for which there is input data available per county, and then area weighted to achieve a final value per year.

Ocean Area

Where used: Used with other data layers in a variety of dimensions for all goals.

Scale: Country scale data.

Description: The coastal and EEZ waters for Israel (bounded by Lebanese, Cypriot, Egyptian and Gaza waters).

Pathogen Exceedance

Where used: Status and trend for clean waters goal, pressure for many goals.

Scale: Updated district data.

Pathogen Pollution

Where used: Status and trend for clean waters goal, pressure for many goals.

Scale: Regional data.

Description: Pathogen indicator data were downloaded from the Israel Ministry of Health website, and are based on Ministry of Health standards[31] for Enteroccoci levels in seawater. Samples containing under 34 bacteria are regarded as "Clean" (value = 0), samples containing between 35 and 104 are regarded as "OK" (value= 0.7), and samples that exceed 104 bacteria per 100 ml are regarded as "Bad" (value =1). The value by region (these are beach-level data that we aggregated to the selected regions in this study using the mean value) is the value of pathogen pollution pressure (x). The status for the Clean Water goal pathogen component is 1-x.

Average Wages

Where used: Status and trend for Livelihoods sub-goal.

Scale: Country scale data.

Description: These data come from the Israeli Central Bureau of Statistics. Data are currently available for 2006-2012 for two economy sectors — tourism and farmed animal culture. These sectors are not marine and are used as proxies. If they keep pace with the growth in average wages or sustain losses comparable to decreases in average wages, the score is 1, i.e., no-net loss occurred. All values were converted from NIS to USD. We then adjusted these dollar estimates for inflation

Employment

Where used: Status and trend for Livelihoods sub-goal.

Scale: Country scale data.

Description: State-level employment (number of jobs) data come from the Israeli Central Bureau of Statistics for the years 2006-2012, and were used as an adjustment factor for job values. This adjustment ensures that changes in the Livelihood sub-goal score reflects only changes specific to jobs in marine-related sectors; if these jobs keep pace with the growth in total jobs or sustain losses comparable to overall decreases in jobs, the score is 1, i.e., no-net loss occurred.

Trash

Where used: Status and trend for clean waters goal, pressure for many goals.

Scale: Regional data.

Description: For the trash layer we used Clean Coast Index[9] reports from the Ministry of the Environment, which reports the amount of plastic trash (>2 cm size) on beaches that are not declared for swimming. We assume that data represent all trash present on the beach.

Amount of Plastic	Clean Coast Index Categories
0-2	Very Clean
2-5	Clean
5-10	Mediocre
10-20	Dirty
>20	Very dirty

The official target for the "Clean Coast Index" is 70% of the beaches clean/very clean 70 % of the time. We revised our target to: all of the beaches clean/very clean 70% of the time, thus conforming with the official targets to a great extent.

UV

Where used: Pressure for several goals.
Scale: Mediterranean and Black Sea analysis[19].
Description: These data come from the Mediterranean and Black Sea analysis[19]. The mapped pressures were transformed to the New Israeli Grid, clipped to the Israeli waters, and rescaled from 0 to 1 (log (x+1)) according to the maximal pressure in the entire Mediterranean and Black Seas data. See Micheli et al. [19], for further information.

Sand Dunes

Where used: Status and trend for coastal protection and biodiversity goals.
Scale: Regional scale data.
Reference condition (C_r): 100% of the areal extent in 1970, which is before most of the coastal construction took place, and is six years after coastal sand mining was prohibited.
Description: Sand dune condition was measured as the change in habitat coverage from 1970 to 2012 within each region by mapping from a high-resolution (25 cm) orthorectified aerial imagery (Survey of Israel 2012) and from Corona Satellite images (1970) for historical extent. For the trend assessment, 2012 mapping was compared with 2006 mapping by Zilberman et al [32]. With the target of zero loss of sand dunes over the time period, the condition is then calculated as 1 – the percent loss of sand dune habitats from 1970-2012. Areas of coastal infrastructure (ports and marinas) were excluded from the analysis, because it would be unrealistic to expect these to be disassembled and replaced by sand dunes.

Soft-Bottom

Where used: Status and trend for biodiversity goal.
Scale: Regional data.

Reference condition (C_r): Zero pressure from bottom-trawl fishing.
Description: We used bottom-trawling pressure on soft-bottom habitats as a proxy for overall habitat condition. Soft-bottom habitat condition was therefore calculated as 1-habitat destruction soft-bottom pressure. See "" for more details.