
# 2018 HAWAIʻI OCEAN HEALTH INDEX

TECHNICAL REPORT
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CONSERVATION INTERNATIONAL

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A collaboration between Conservation International and the University of Santa Barbara National Centr for Ecological Analysis and Synthesis Ocean Health Index team

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# SUMMARY

The Hawai‘i Ocean Health Index is a scientifically robust index that measures ocean health for Hawai‘i. It is supported by local stakeholders and integrates policy initiatives to support sustainable ocean management. The Ocean Health Index framework allows for repeatable assessments of the index goals overtime to measure progress toward a common vision for a healthy ocean and sustainable ocean management for Hawai‘i. The 2018 assessment of the Hawai‘i Ocean Health Index provides an opportunity to assess priorities for strengthening ocean resource management. Six goals or priorities were assessed in the 2018 Hawai‘i Ocean Health Index: Food Provision (subgoals: Offshore Fisheries, Nearshore Fisheries, and Mariculture), Coastal Protection, Biodiversity (subgoals: Habitats and Species), Economies & Livelihoods, Sustainable Tourism, and Sense of Place. The goals were assessed for four regions, and also combined into a single score for the Main Hawaiian Islands as a whole. Goals are modeled with the best available data, resulting in scores that indicate how close each region is to meeting explicit targets. The Main Hawaiian Islands received a score of 74, with Maui Nui having the highest regional Ocean Health Index score (79), followed by Kaui‘i and Ni‘ihau (76), Hawai‘i (72), and O‘ahu (69). Ocean Livelihoods & Economies received the highest score, with Hawai‘i’s ocean economy providing 16% of Hawai‘i’s jobs and $18 billion annually in revenue. Goals that incorporated ocean and coastal habitat health or protection tended to score the lowest, highlighting the need to protect or restore these habitats. These goals are Biodiversity, Coastal Protection, and Sustainable Tourism. Protecting and restoring these habitats is essential to sustaining our community and economy now and into the future.

# BACKGROUND

## WHAT IS THE OCEAN HEALTH INDEX?

The Ocean Health Index (OHI) is the first integrated assessment framework that scientifically combines key biological, physical, economic, and social elements of the ocean’s health (Halpern et al. 2012). Overall Index scores are a combination of components, or ‘goals’, of ocean health. These scores are calculated using the best available data and indicators at the scale of the assessment. Scores reflect how well coastal regions optimize their potential ocean benefits and services in a sustainable way relative to a reference point (target), on a scale of 0-100.

Methods for calculating the OHI were developed at a global scale, combining dozens of data sets to produce annual Index scores for coastal nations and territories (Halpern et al., 2012), and have been repeated annually with a focus on improving methods and data (Halpern et al. 2015; 2017; Lowndes et al. 2017; ohi-science.org). As a result, for the first time, we are able to assess and compare global performance in managing our relationship with the Earth’s greatest resource—the Ocean. Using the same framework, independent assessments (OHI+) allow for exploration of variables influencing ocean health at the smaller scales where policy and management decisions are made. Targets for goals are created using stakeholder input, higher resolution data, indicators, and priorities, which produce scores that better reflect local priorities. This enables communities, managers, policy makers, scientists to better and more holistically understand, track, and communicate the status of local marine ecosystems, and to design strategic management actions to improve overall ocean health.

## ADAPTING THE INDEX FOR HAWAI‘I

Hawaiians have a long history of sustainable management and resource use and have long recognized that their wellbeing and health relied on the status or availability of their resource. Today, the same is true; the health of our island communities and our environment is intertwined. Healthy communities are more equipped to be stewards of their environment and a healthy environment supports community wellbeing. This strong sense of place and mālama ‘āina (care for the land and ocean) drives community conservation in Hawai‘i and is a model for the rest of the world. These social and cultural values are the foundation for the development of the Hawai‘i Ocean Health Index with social and cultural values embedded into each goal. The index was developed by a diverse group of stakeholders including community members, non-profit groups, private industries, and state and federal agencies to communicate the status of our ocean resources and create a shared vision for the future of our oceans.

Practicing hula looking out to the ocean as the sun sets. Photo: Conservation International photo by S. Kēhaunani Springer.

# METHODS

## OHI FRAMEWORK

Ocean health was defined as an ocean that can provide benefits and services for people now and into the future. Furthermore, health was defined as a state of being that is pono (sustainable/respectful); where functions and processes can exist, perpetuate, and evolve, including

Table 1. Locally defined goals for the Hawai‘i Ocean Health Index.

| Goal | Subgoal | Definition |
|---|---|---|
| Food Provision (FP) | Nearshore Fisheries (NFI) | Food Provision measures the availability of sustainably harvested or cultured seafood. Offshore Fisheries measures of the amount and sustainability status of wild-caught seafood from pelagic, bottomfish, and coastal pelagic fisheries from formal stock assessments. Nearshore Fisheries measures of the status of nearshore fish populations for the benefits that they provide to local subsistence and culture. Mariculture measures the sustainable production of seafood from contemporary mariculture and customary Hawaiian fishponds (loko i‘a). |
| | Offshore Fisheries (OFI) | |
| | Mariculture (MAR) | |
| Sense of Place (SP) | | Sense of Place measures the value and relationships between people and the ocean and coastal areas. This goal measures the frequency of ocean and coastal activities that occur in each place including recreational and cultural activities. |
| Sustainable Tourism (ST) | | Sustainable Tourism measures the balanced economic growth through tourism with management and preservation of natural resources and Hawaiian culture. |
| Biodiversity (BD) | Habitats (HAB) | Biodiversity measures the value of coastal and ocean species and habitats. Habitats measures the extent and condition of reefs, wetlands, soft-bottom habitats, and beaches. Species measures the population status of Hawai‘i species based on reef fish biomass and the risk of extinction of marine mammals, turtles and birds, and coastal beach and sand dune plants. |
| | Species (SPP) | |
| Coastal Protection (CP) | | Coastal Protection measures the extent and condition of habitats (beaches, coral reefs, wetlands) that provide coastal protection from inundation and erosion. |
| Livelihoods & Economies (LE) | Livelihoods (LIV) | Livelihoods & Economies measures the coastal and ocean-dependent jobs and coastal economies from marine related industries including tourism, fishing, shipbuilding, and transportation. Livelihoods tracks the number of jobs and the quality of jobs (wage/livable wage) of marine sectors and Economies tracks the revenue generated from productive coastal economies. |
| | Economies (ECO) | |

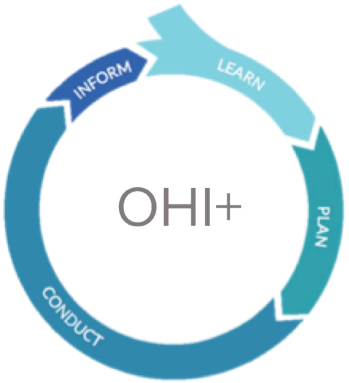
the presence and role of humans. Our common vision for ocean health in Hawai‘i is a resilient and productive system that provides services and resources to sustain Hawai‘i’s residents and economy now and into the future.

The global Ocean Health Index (OHI) developed 10 goals that encompass ocean health: Food Provision, Natural Products, Clean Water, Coastal Protection, Carbon Storage, Biodiversity, Tourism & Recreation, Livelihoods & Economies, Artisanal Fishing Opportunities, and Sense of Place. For the Hawai’i OHI, these goals were adapted from the global framework and transformed into six goals: Food Provision, Coastal Protection, Biodiversity, Economies & Livelihoods, Sustainable Tourism, and Sense of Place (Table 1)

## PROCESS FOR DEVELOPING THE HAWAI‘I OHI

The Ocean Health Index was developed for Hawai‘i through the support of local experts, stakeholder surveys, working groups, workshops, and meetings. A coalition for sustainable ocean management was built through bringing together management agencies, stakeholders, and organizations to support sustainable

**The OHI Process**




Learn about the Ocean Health Index and its applications

Plan the assessment to achieve local objectives and involve stakeholders

Conduct assessment with adapted framework and local data on status, pressures, and resilience

Inform testing management options, support sustainable actions, and increase collaboration & communication

Repeat assessment process incorporating updated science and policies to track progress towards a healthy ocean

ocean management through a clear vision of ocean health and a united common goal of assessing and tracking ocean health in Hawai'i. The conceptual framework of the Hawai'i OHI assessment was adapted from the global OHI framework to meet Hawai'i's unique ecological, social, economic, and cultural aspects.

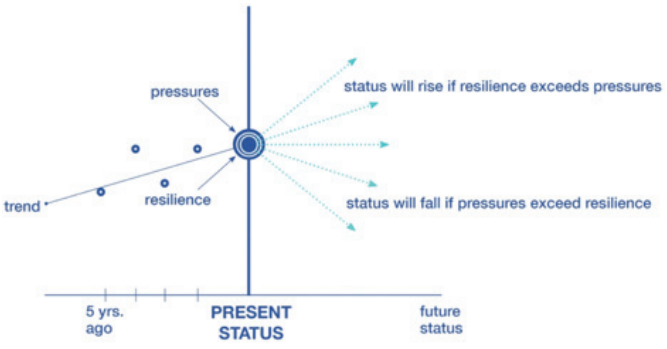
## SYNERGIES WITH EXISTING REGIONAL AND STATEWIDE OCEAN SUSTAINABILITY INITIATIVES

The Hawai'i OHI incorporates the Hawai'i Ocean Resource Management Plan (ORMP) and priorities that are tracked within the plan. The Hawai'i ORMP is a statewide plan that sets forth the State's ocean and coastal resource management priorities. It supports effective management, beneficial use, protection, and development of the state's coastal zone, which includes all lands of the state and the area extending seaward from the shoreline to the limit of the State's police power and management authority, including the U.S. territorial sea. The ORMP is a requirement under Hawaii Revised Statutes §205A-62(1) and is a major component of the State's Coastal Zone Management Program.

The Hawai'i OHI is also part of the Aloha + Challenge, Hawai'i's statewide commitment to achieve six integrated sustainability goals by 2030 for clean energy, local food, natural resource management, solid waste, smart sustainable communities and green education and workforce. Progress on the six goals and climate commitment is measured on the Aloha + Challenge Dashboard, which can be viewed online at dashboard.Hawai'i.gov/aloha-challenge. In particular the Hawai'i OHI incorporates the initiatives to protect 30% of priority watersheds by 2030 and effectively manage 30% of nearshore ocean waters by 2030 into the targets for the Sustainable Tourism goal.

The Aloha + Challenge: He Nohona 'Ae'oia, A Culture of Sustainability is recognized by the United Nations (UN) and the international community as a place-based model to achieve the global 2030 Sustainable Development Goals. Building on the 2016 IUCN World Conservation Congress, Hawai'i is working with the Global Island Partnership and the UN Development Programme to scale the Aloha+ Challenge with Pacific Island leaders to support locally and culturally appropriate action on the global agenda.

## CALCULATING THE INDEX




**Index, Regional, and Goal Scores**

The index (I) score is the sum of the regional scores ($I_{region}$). All regions were given equal weight in the index ($\alpha$).

$$I = \sum_{i=1}^{N} \alpha_i I_{region,i}$$

The regional scores ($I_{region}$) are the sum of all the individual goal scores ($G_i$). All goals were given equal weight in the index ($\alpha$).

$$I_{region} = \sum_{i=1}^{N} \alpha_i G_i$$

The goal score ($G_i$) is the average of current status (50% of the goal score) and probable future state (50% of the goal score).

$$G = \frac{x + x_f}{2}$$

The goal current status (x) is calculated using available indicators in relation to a stakeholder set reference point (see goal models & data below for specific models for each goal). The probable future status ($x_f$) measures the cumulative pressures (negative impacts on a goal score), cumulative resilience (positive impacts on a goal score) and trend (projected goal status in five years). The future status score is the near future score projection of a goal calculated as the current goal status multiplied by the 5 year status trend (T) and the difference in the resilience (r) and pressure (p) applied to that goal (Halpern et al., 2012).

$$x_{i,f} = [1 + \beta T_i + (1-\beta)(r_i - p_i)]X_i$$

The trend is given a higher weight ($\beta$) than the pressure/resilience component. This value was chosen based on the assumption that trend is a better indicator of the near future condition than indirect measures of pressure and resilience (Halpern et al., 2012). All pressure and resilience values are scaled from 0 to 1 and trend is constrained to -1.0 to +1.0.

Pressures and Resilience

Cumulative pressures acting on each goal are calculated as the sum of ecological ($P_E$) and social pressures ($P_S$):

$$p = \gamma * p_E + (1 - \gamma) * p_S$$

Where $\gamma$ is the relative weight for ecological vs. social pressures, set as equal (0.5).

Each pressure layer is assigned to an ecological or social category, with ecological pressures further assigned to one of five subcategories (pollution, alien species, habitat destruction, fishing pressure, and climate change). Each ecological pressure layer is then applied to relevant goals and assigned a rank sensitivity or the weight of the pressure on that goal from 1 to 3 with 1 being low impact, 2 being medium impact, and 3 being high impact. Ecological pressures are then calculated as the weighted average of the pressure scores for each category for each goal (see Halpern et al. 2012). Social pressures are unweighted, and the social pressure exerted on a goal is calculated as the average of the all the social pressures applied to that goal (Halpern et al. 2012).

Resilience layers are assigned to three categories: ecological integrity, regulatory efforts, and social integrity.

Ecological integrity and regulatory effort resilience scores address ecological pressures and therefore are averaged together and added to the social integrity resilience scores for each goal (Halpern et al. 2012).

The pressure and resilience layers help capture the complex interactions social and ecological interactions that are exerted on each goal. For example, increased visitors can support Livelihoods & Economies but can exert a pressure on habitat health and therefore reduce Biodiversity. These interactions are captured in the OHI through pressure and resilience layers that are scored and applied to each goal. See the section on Data Layers for a full list of the pressures and resilience layers that are applied to each goal.

**Spatial Extent**

The Hawai'i OHI was a statewide assessment for the Main Hawaiian Islands. The assessment was done at the county scale (Hawai'i, Maui Nui, O'ahu, and Kaua'i) and averaged to produce the overall Hawai'i OHI score. The OHI focus is on the entire EEZ, however, some goals are assessed on the nearshore (3 nm) scale (Table 2).

Table 2. Spatial extent for goal models.

| Goal | Sub-Goal | Spatial Scale |
|---|---|---|
| Food Provision | Nearshore Fisheries | Nearshore |
| | Offshore Fisheries | EEZ |
| | Mariculture | Nearshore |
| Sense of Place | | Nearshore |
| Sustainable Tourism | | Nearshore |
| Biodiversity | Species | EEZ |
| | Habitats | EEZ |
| Coastal Protection | | Nearshore |
| Livelihoods & Economies | Livelihoods | EEZ |
| | Economies | EEZ |

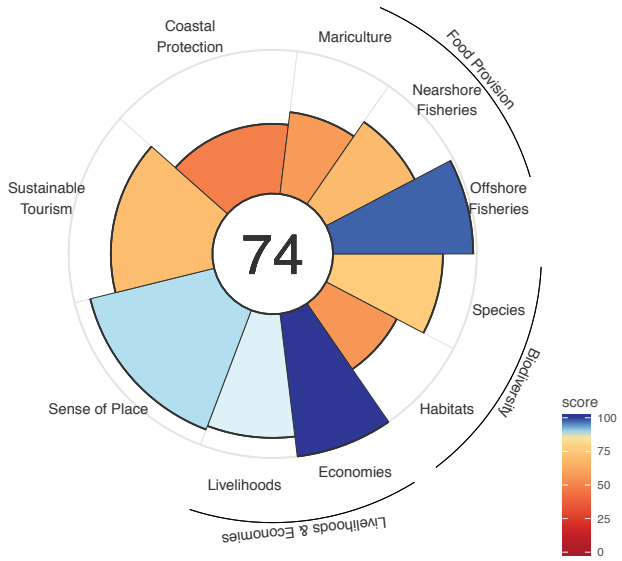
# RESULTS

## SCORES

The Main Hawaiian Islands scored 74 out of a possible 100. Overall, Hawai'i's Livelihoods & Economies, Sense of Place, and Offshore Fisheries had high scores. However, the coastal and ocean habitats that underpin many of the other goals are impacted, with goals that incorporate coastal and ocean habitats receiving low scores.

Livelihoods & Economies scored the highest (93) out of the six goals assessed, with the subgoal of Economies receiving a perfect score (100). This reflects the steady revenue generated from marine and coastal industries in Hawai'i.

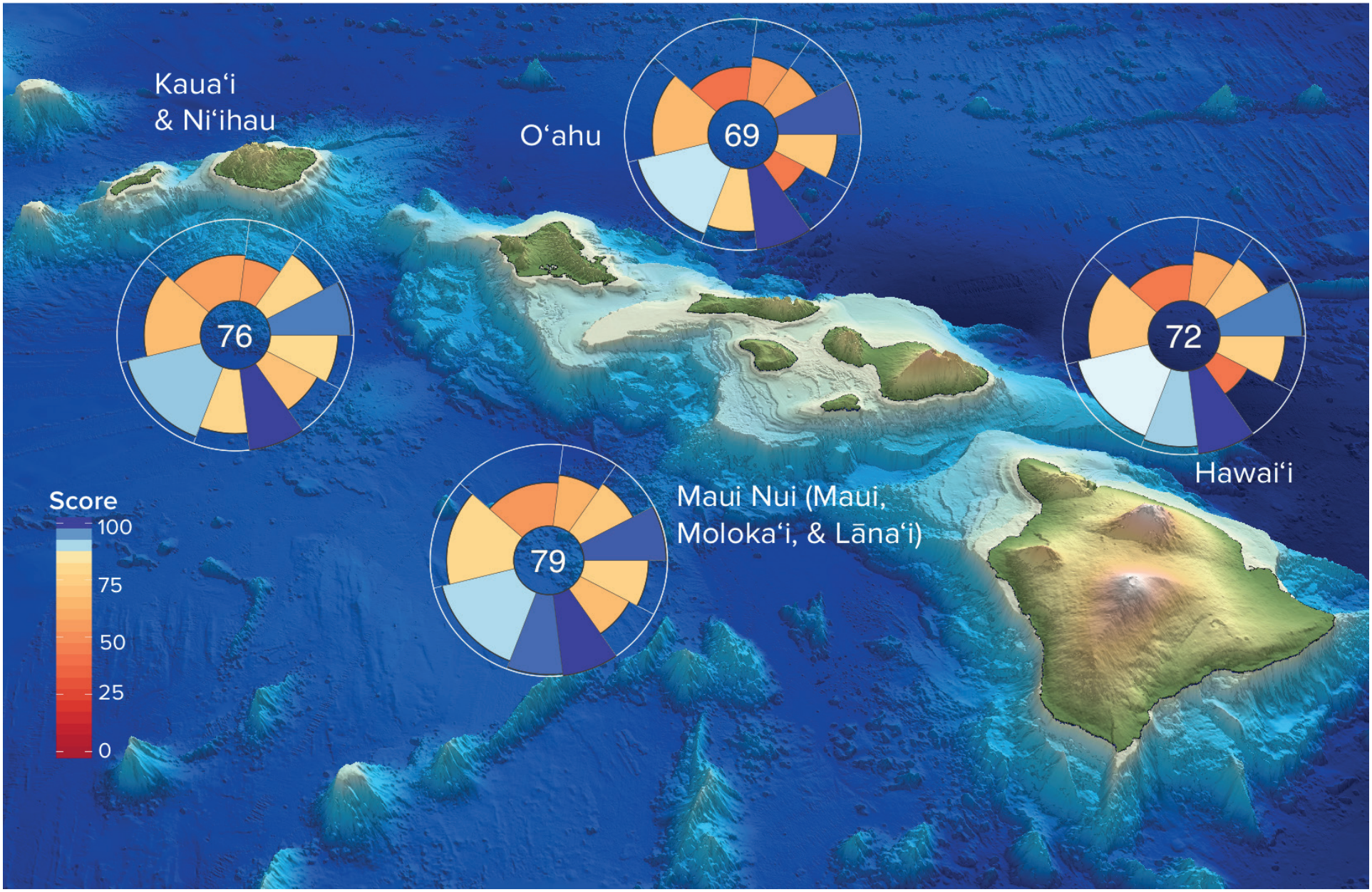
Coastal Protection revieced the lowest score of 49 out of a possible 100. Biodiversity scored 66 with the Habitats subgoal scoring 56, the second lowest score wihtin the index, and the Species subgoal scoring 89. The Mariculture subgoal of Food Provision recieved the third lowest score of 57.




Scores for Main Hawaiian Islands. Scores are represented by color and petal plot length. Longer petal length and darker blue colors represent higher sores. These scores are an average of the four regions assessed (Hawai'i, Maui Nui, O'ahu, and Kaua'i & Ni'ihau.

Table 3. Goal scores for the Hawai'i Ocean Health Index (FP=Food Provision, BD=Biodiversity, LE=Livelihoods & Economies, NFI=Nearshore Fisheries, OFI=Offshore Fisheries, MAR=Mariculture, HAB=Habitats, SPP=Species, LIV=Livelihoods, ECO= Economies, SP=Sense of Place, ST=Sustainable Tourism, CP=Coastal Protection).

| Region | Index | FP | | | BD | | LE | | SP | ST | CP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NFI | OFI | MAR | HAB | SPP | LIV | ECO | | | |
| Main Hawaiian Islands | 74 | 70 | 98 | 57 | 56 | 77 | 86 | 100 | 89 | 71 | 49 |
| Hawai'i | 72 | 70 | 97 | 60 | 42 | 76 | 91 | 100 | 86 | 70 | 42 |
| Maui Nui | 79 | 72 | 98 | 63 | 67 | 77 | 98 | 100 | 90 | 80 | 53 |
| O'ahu | 69 | 59 | 99 | 54 | 43 | 71 | 77 | 100 | 88 | 66 | 41 |
| Kaua'i & Ni'ihau | 76 | 78 | 97 | 52 | 69 | 81 | 79 | 100 | 91 | 68 | 56 |




Regional scores for Hawai‘i County, Maui County, O‘ahu County, and Kaua’i County. Regional scores varied across counties and are based on regional differences in the local economic, social, and ecological indicators that underpin the index. Maui Nui had the highest regional Ocean Health Index score (79), followed by Kaui‘i and Ni‘ihau (76), Hawai‘i (72), and O‘ahu (69).

# GOAL SCORES & DESCRIPTIONS

## FOOD PROVISION

Over half (55%) of available seafood in Hawai'i is locally sourced (Teneva et al. 2018). Nearly 34 million lbs. (99%) comes from nearshore and offshore fisheries and 0.35 million lbs. (1%) comes from mariculture. The majority of Hawai'i's catch is from the pelagic fishery, followed by the reef fishery (commercial & non-commercial catch), coastal pelagic fishery, and bottomfish fishery (Table 4).

Table 4. Mean annual catch from Hawai'i's fisheries. A multiplier is applied to the reef fishery to account for the estimated non-commercial catch (McCoy et al., 2018).

| Fishery | Mean Annual Catch (lbs.) |
|---|---|
| Reef | 2,694,641 |
| Bottomfish | 428,181 |
| Coastal Pelagic | 583,030 |
| Pelagic | 30,230,053 |

**Nearshore Fisheries**
Nearshore Fisheries are extremely valuable for providing food and cultural resources for Hawai'i. The majority of nearshore catch does not go to markets with up to 90 percent kept by fishers or given away for home consumption showing the value of this fishery for providing local meals and supporting cultural practices.

This goal was assessed as the measure of available nearshore fish biomass, or in other words, the availability of the resource. Nearshore Fisheries scored an average of 70 for the Main Hawaiian Islands. Nearshore fisheries scores were lowest on O'ahu at 59 out of a possible 100.

**Offshore Fisheries**
Offshore Fisheries scored 98 reflecting that the majority of catch from pelagic and bottomfish comes from sustainable fisheries. Scores are assessed on the stock status of both pelagic and bottomfish fisheries, with species that comprise the majority of Hawai'i's catch contributing more to the overall score.

In 2016, Hawai'i's pelagic fishery was composed primarily of bigeye tuna (16M lbs), yellowfin tuna (4M lbs) and swordfish (2M lbs), followed by ono, marlin, mahimahi and monchong contributing 1M to 2M lbs each.

The bottomfish fishery is a multispecies fishery. In 2016, opakapaka (131K lbs) and uku (110K lbs) comprised the majority of the catch.

**Mariculture**
Production of edible seafood is relatively low compared to Hawai'i's wild caught fisheries, representing 1% of the total seafood production. Mariculture production in Hawai'i comes from contemporary mariculture production (also referred to as aquaculture) and from traditional Hawaiian fishponds, known locally as loko i'a. Historically, seafood from traditional Hawaiian fishponds played a large role in sustaining Hawaiian populations. In the early 1900s, Hawaiian fishponds produced 400-600 lbs. of seafood per acre (Honua Consulting, 2013). Today, it is estimated that 422 fishponds remain, with a small proportion of them that are capable of producing seafood, however many of these are being restored to viable seafood production systems. The number of remaining fishponds was used as a metric for seafood production potential and is part of the mariculture score along with contemporary mariculture production system.

Several species of finfish and shellfish are grown in Hawai'i for food consumption. However, many of the mariculture species grown in Hawai'i do not support local food provision such as microalgae and brood stock shrimp. Therefore, while revenue is high for Hawai'i's mariculture industry ($78 Mil in 2014; (HDA)), the yield or production of edible seafood is relatively low compared to Hawai'i's wild caught fisheries. Mariculture scored 57, reflecting the variability in the yield from contemporary mariculture systems and the potential risk and sustainability of the species cultured and loss of Hawaiian fishponds. Future projections show that local seafood production will meet only 45% of the local seafood demand by 2040 (Teneva et al 2018). Therefore, mariculture may play a larger role in future seafood production in the future.

## SENSE OF PLACE

Cultural values are expressed in the development of this goal and several of the other goals, as local and cultural values are recognized as important to all aspects of ocean health. This goal stresses the importance of the ocean and coastal areas for maintaining cultural practices, community wellbeing, and general sense of place. An important component identified for sense of place is the connection or relationship that people have with the ocean and coastal areas. How we use ocean areas can in part define our connection and values towards them thus Sense of Place is measured through resident participation rates in ocean activities. On average, 89% of Hawai'i residents participate in an ocean activity at least once a month (Table 5).

Table 5. Hawai'i resident participation rates in ocean activities at least once per month.

| Region | Participation Rate |
|---|---|
| Hawai'i | 89 |
| Maui Nui | 92 |
| O'ahu | 92 |
| Kaua'i & Ni'ihau | 94 |

## SUSTAINABLE TOURISM

This goal measures the balance between economic growth through tourism with management and preservation of natural resources and Hawaiian culture. This is measured through tracking visitor generated revenue, ocean and coastal management areas to preserve the environment and provide visitor ecotourism opportunities, and the sentiment of residents towards tourism. Sustainable tourism was scored based on the benefit of visitors to economic growth while taking into account the preservation of social and cultural values of residents and protection of the natural environment.

Scores ranged from 65 to 80 by region, with Maui Nui receiving the highest score. The relatively low scores reflect the need to balance the economic gains with the preservation of Hawai'i's unique cultural and natural environment. Tourism contributed $18 billion in direct visitor generated revenue in 2016, contributing >14% to Hawai'i's GDP from visitor spending alone. However, increased stewardship and protection is needed to balance the increased human use from visitors on ocean and coastal areas. Currently 13% of nearshore waters are protected by marine management areas, with the target set at 30% protection by 2030 (State of Hawai'i). The definition and assessment of effective management areas to meet the 30% target is currently being developed by the Department of Land and Natural Resources Division of Aquatic Resources and will be incorporated into future assessments. Additionally, watershed protection is included in this goal for the benefits that watersheds provide such as freshwater retention and reducing water pollution and soil erosion to the nearshore environment. Currently 15.3% of priority watersheds are protected (Yuen, 2017), the target set at 30% protection by 2030 (State of Hawai'i). Lastly, resident sentiment is included as a metric in this goal, with resident's sentiment or satisfaction of tourism currently at 68% and has been steadily declining over the past 7 years (HTA, 2017).

Stakeholders have identified several areas to increase the preservation of social and cultural values and the natural environment. These include increased tourism education programs, increased proportion of the tax revenues generated from the tourism industry allocated to community and environmental preservation and increased freshwater reserves to accommodate both residents and visitors.

## BIODIVERSITY

Biodiversity measures the value Hawai'i's unique and diverse coastal and ocean habitats and species.

**Habitats**

Coastal habitats assessed include soft bottom (bays), wetlands, beaches, and coral reefs. These habitats and the species that reside in them are the foundation of many of the benefits that we receive from the ocean including food provision, coastal protection, sustainable tourism, sense of place, and our livelihoods and economy. However, our ocean and coastal habitats surrounding the Main Hawaiian Islands are threatened and we are seeing the impacts of coastal pollution, unsustainable development, and climate change on the resulting habitat condition. Hawai'i's ocean habitats are in average to poor condition with 54% of historical coastal wetlands intact, coral reef condition declining drastically with increased water pollution and recent coral bleaching events, and the extreme erosion of our coastlines, with 72% of beaches actively eroding (Table 6). Protecting and restoring these habitats is essential to sustaining our community and economy now and into the future.

Table 6. Habitat extent and condition by region.

| Region | Habitat | Condition | Extent |
|---|---|---|---|
| Hawai'i | beach | 28 | 55.9 km |
| Maui Nui | beach | 15 | 144.1 km |
| O'ahu | beach | 40 | 140.8 km |
| Kaua'i & Ni'ihau | beach | 29 | 133.6 km |
| Hawai'i | reef | 66 | 238.6 $km^2$ |
| Maui Nui | reef | 64 | 461.3 $km^2$ |
| O'ahu | reef | 60 | 374.2 $km^2$ |
| Kaua'i & Ni'ihau | reef | 61 | 347.3 $km^2$ |
| Hawai'i | soft bottom | 61 | 17.0 $km^2$ |
| Maui Nui | soft bottom | 98 | 156.2 $km^2$ |
| O'ahu | soft bottom | 49 | 92.8 $km^2$ |
| Kaua'i & Ni'ihau | soft bottom | 99 | 56.0 $km^2$ |
| Hawai'i | wetland | 25 | 0.2 $km^2$ |
| Maui Nui | wetland | 75 | 11.9 $km^2$ |
| O'ahu | wetland | 29 | 6.7 $km^2$ |
| Kaua'i & Ni'ihau | wetland | 85 | 3.8 $km^2$ |

**Species**

Hawai'i's ocean is home to over 565 endemic marine species. This means that over 20% of Hawai'i's marine fishes can be found nowhere else on earth. The Endangered Species Act (ESA) was established in 1973 to provide for the conservation of species that are endangered or threatened (likely to become endangered in the near future without protection) throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend.

The Species subgoal of Biodiversity measures the species status based on the percent of species listed on the Endangered Species List and on the population status of Hawai'i coral reef fish species. Species scored 77, with the majority of marine species (marine, mammals, turtles, shorebirds and seabirds, and coastal sand and dune plants) not listed as threatened or endangered. However, while fish and coastal plants scored fairly well, sea and shore birds and marine mammals and turtles are the most

threatened. Seabirds and shorebirds has the highest rate of endangered, threatened, or listed species of concern (53%), followed by marine mammals and turtles with 39% of Hawai'i's marine mammals and turtles listed on the Endangered Species List.

### COASTAL PROTECTION

Coastal Protections measures the extent and condition of habitats that provide coastal protection. Coral reefs, wetlands, and beaches protect Hawai'i's coastline from flooding and inundation. Coastal Protection received a score of 49. A score of 100 would indicate that these habitats are all still intact or have been restored to their reference conditions. Beach habitat was scored based on the percent of beaches that are not actively eroding, receiving very low scores, with over 72% of beaches actively eroding across Hawai'i. Wetland habitat was scored based on the current coastal wetland habitat compared to historical extents, with many of the historical coastal wetlands filled in and lost through coastal development. Lastly, coral reefs were scored based on several benthic indicators such as coral cover, algae cover, coral mortality, and juvenile and adult coral densities. Coral reefs scored lowest on O'ahu and highest on Hawai'i Island.

Coastal protection scores also take into account pressures such as climate change on these coastal habitats. Climate change poses a huge threat to coastal communities and Hawai'i's economy. Sea level rise is projected to cause increased coastal erosion and inundation, furthering the importance of our coastal habitats to buffer against these changing ocean conditions (Hawai'i Climate Change Mitigation and Adaptation Commission).

### LIVELIHOODS & ECONOMY

Ocean revenues contribute over 6 billion to Hawai'i's economy each year and directly provide 16% of jobs (103,427 in 2013) (Table 7). The Livelihoods & Economies goal scored 93 and reflects the ability of ocean sectors to provide livelihood opportunities, and consistent or stable revenue generated from ocean sectors.

Livelihoods measures job quantity and quality for people living on the coast. 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. The tourism and recreation sector represent between 85% to 99% of the total ocean sector jobs per county. Mean wage is lowest in this sector at $20,919 in 2013. This is 48% lower than the state mean wage (DBEDT) and 36% below the self-sufficiency standard (DBEDT, 2015).

Economies captures the economic value associated with marine industries using revenue from marine sectors. Ocean revenues contribute over $6 billion to Hawai'i's economy annually and have remained stable over the past five years.

Table 7. Ocean contribution to Hawai'i's livelihoods and economy.

| Region | Total Ocean Sector Jobs | Percent of Jobs per Region | Revenue (mil) |
|---|---|---|---|
| Hawai'i | 13,576 | 16% | 993.2 |
| Maui Nui | 25,423 | 32% | 2,165.5 |
| O'ahu | 59,164 | 13% | 2,700.1 |
| Kaua'i & Ni'ihau | 5,264 | 16% | 217.9 |

# GOAL MODELS & DATA

The following section outlines the models and data used to develop each goal and subgoal in the Hawai'i Ocean Health Index. All of the data for this assessment is available at ohi-science.org/mhi. The current data gaps that were identified during the assessment are listed at the end of each goal and subgoal section.

## FOOD PROVISION

This goal measures the sustainably harvested and produced seafood from fisheries and aquaculture (local production of seafood including shrimp ponds and fishponds) in Hawai'i.

$$X_{FP} = \frac{X_{fis} + X_{mar}}{2}$$

**Nearshore Fisheries**

This subgoal of Food Provision measures the availability of nearshore fisheries resources for subsistence, recreational, and commercial fisheries.

Nearshore Fisheries is measured as the average of 3 components: Reef Fish Biomass, Reef Fish Sustainability, and Reef Fish Predators (NOAA Coral Reef Conservation Program and University of Maryland Center for Environmental Science). Reef Fish Biomass measures the mean biomass of all reef fishes other than sharks and jacks derived from underwater visual surveys of <30m hard bottom habitats. Survey biomass per location is compared against a meaningful local baseline (to account for inherent environmental and habitat differences among locations). Reef Fish Sustainability represents an index of mean size for targeted reef fish species relative to their size at first maturity. High scores therefore represent assemblages where there are still many large individuals of targets species, those large fishes being particularly important components of the breeding stock. The Reef Fish Predators indicator is made up of 2 components: 'reef sharks' and 'other reef piscivores' with data taken respectively from towed-diver and point-count surveys

by divers. High scores represent locations where upper trophic level fishes are still a conspicuous and ecologically important component of the reef ecosystem.

**Offshore Fisheries**

This subgoal of Food Provision measures the amount harvested and sustainability of Hawai'i's fisheries. The model generally compares landings with Maximum Sustainable Yield.

$$X_{fis} = \sum_{i=1}^{n} Fishery_i \prod_{i=1}^{n} SS_i^{\frac{C_i}{\sum C_i}}$$

Where Fishery is the pelagic, bottomfish, or coastal pelagic fishery, SS is the stock status scores, and C is the catch.

The model assesses the amount of wild-caught seafood that can be sustainably harvested from within the Hawai'i EEZ, with sustainability (stock status scores) based on formal stock assessments. Catch data was provided by The Department of Land and Natural Resources Division of Aquatic Resources (DLNR DAR).

Stock status scores were calculated as the mean of the all stock status scores for each fishery (pelagic: tuna, swordfish, mahimahi, etc.; bottomfish: deep seven species mainly groupers and snappers; coastal pelagics: jacks, akule, 'ōpelu, etc). Longline data for pelagic species landed in Hawai'i but caught outside of the OHI assessment region (Main Hawai'i Island EEZ) was included in the assessment. Each stock is assessed separately based on stock status scores (Biomass at maximum sustainable yield: B/Bmsy or Spawning biomass at maximum sustainable yield: SB/SBmsy). We applied a 0.05 lower buffer on the stock status score allowing for error in the stock status. Sustainability scores above 1.00 were given a score of 1.00.

Stock status reference points used in formal stock assessments vary by the fishery type. The pelagic fish sustainability reference point was SB/SBmsy, with a reference value of 1.0. The bottomfish species sustainability reference point was B/BMSY, with a reference value of 1.0. The most recent stock assessments for pelagic fish species were 2012-2013 for most species (WCPFC; ISC, 2017). Therefore, the ten most recent years of stock assessment data was used to run a linear regression model to predict stock status to 2016. If stock status was non-linear then the mean stock status was used. Bottomfish stocks were assessed as a species complex (Langseth et al., 2018). We used median scores for each fishery (pelagic, bottom, coastal pelagic) to gap fill for species that lacked formal stock assessments. To include these important harvest species, we made the assumption that the unassessed species within each fishery (pelagic, bottomfish, coastal pelagic) are faring similarly to the assessed fish stocks. There were no current formal stock assessments for coastal pelagic species (scores are reported as NA) and therefore they are not incorporated into the score for this goal, but they are included in the catch data for reference, comprising approximately 2% of commercial catch.

Table 8. Mean annual catch (lbs) from 2012 to 2016 and sustainability scores for coastal pelagic species.

| Species | Mean Annual Catch (lbs) | Score |
|---|---|---|
| Akule | 313,584 | NA |
| Barred jack | 50 | NA |
| Dobe ulua | 3,348 | NA |
| Halalū | 17,899 | NA |
| Kagami ulua | 221 | NA |
| Kamanu | 4,355 | NA |
| Lae | 254 | NA |
| Omaka | 28 | NA |
| 'Ōmilu | 6,846 | NA |
| 'Ōpelu | 223,704 | NA |
| 'Ōpelu mama | 40 | NA |
| Paopao ulua | 525 | NA |
| Papa ulua | 8,569 | NA |
| Sasa ulua | 393 | NA |
| Ulua-misc. | 1,751 | NA |
| Shark-misc. | 2,346 | NA |

Table 9. Mean annual catch (lbs) from 2012 to 2016 and sustainability scores for bottomfish species.

| Species | Mean Annual Catch (lbs) | Score |
|---|---|---|
| Alfonsin | 35 | 1.00 |
| Butaguchi ulua | 306 | 1.00 |
| Gunkan ulua | 366 | 1.00 |
| Kāhala | 15,621 | 1.00 |
| White ulua | 13,177 | 1.00 |
| Ehu | 30,173 | 1.00 |
| Gindai | 3,001 | 1.00 |
| Kalekale | 14,257 | 1.00 |
| Lehi | 10,332 | 1.00 |
| Onaga | 61,830 | 1.00 |
| 'Ōpakapaka | 130,982 | 1.00 |
| Ta'ape | 31,373 | 1.00 |
| Uku | 110,802 | 1.00 |
| Hapu'upu'u | 9,194 | 1.00 |

Table 10. Mean annual catch (lbs) from 2012 to 2016 and sustainability scores for pelagic species.

| Species | Mean Annual Catch (lbs) | Score |
|---|---|---|
| Thresher shark | 20,118 | 0.80 |
| Monchong | 1,168,014 | 0.83 |
| Blue | 17,780 | 1.00 |
| Oceanic shark | 462 | 1.00 |
| Mahimahi | 1,661,441 | 0.83 |
| Blue marlin | 1,489,631 | 1.00 |
| Misc Istiophoridae | 2,234 | 0.68 |
| Sailfish | 46,248 | 0.68 |
| Striped marlin | 1,005,382 | 0.36 |
| Mako | 119,501 | 0.80 |
| Bigeye tuna | 16,523,199 | 1.00 |
| Bluefin | 1,077 | 0.25 |
| Kawakawa | 18,179 | 0.80 |
| Ono | 1,075,297 | 0.81 |
| Tombo | 925,796 | 1.00 |
| Yellowfin tuna | 4,070,707 | 1.00 |
| Swordfish | 2,084,987 | 1.00 |

Data Gaps

- Species specific stock assessments for bottomfish, as bottomfish taxonomic resolution for the stock assessment was not assessed to species.
- Public perception of fisheries status.
- Estimates of non-reported commercial catch.
- Dealer reporting data.
- Lacking stock assessments for many of the harvested fish species and all of the coastal pelagic species.

**Mariculture**

This subgoal of Food Provision measures the sustainable production potential of seafood from fishponds and current production of seafood weighted by a sustainability score. The scores are an average of the state reported seafood production (aquaculture) and fishpond potential.

$$X_{mar} = \frac{X_c + X_t}{2}$$

$$X_c = \frac{\sum_{i=1}^{n} y_{c,i}}{\sum_{i=1}^{n} y_{r,i}} * S$$

$$X_t = \frac{f_c}{f_r}$$

Where $X_C$ is the contemporary mariculture production and $X_t$ is the traditional production from Hawaiian fishponds. $X_C$ is measured as the sum of the yield ($y_c$) from each reported mariculture category (i) (finfish and shellfish) compared to the annual maximum yield for each region ($y_r$) over the last five years of available data and weighted by the average species sustainability score. The production (yield: lbs. of seafood) is reported at the state level to prevent disclosure of sensitive information (HDA). To get county level estimates of production, the yield of finfish and shellfish produced at the state level were multiplied by the estimated proportion of finfish and shellfish operators by county. The number of operators are reported to USDA via census every 5 years (2002, 2007, 2012) (USDA). To fill in annual data gaps linear regression models were used.

The species that are reported on the State Department of Land and Natural Resources Division of Aquatic Resources that are produced locally for seafood consumption include: Abalone (*Haliotus sp*), oysters (*Crassostrea gigas* and *Crassostrea sikamea*), clams (*Venerupis philippinarum*), kāhala (*Seriola dumerili*), Pacific White Shrimp (*Penaeus vannamei*), limu (*Gracilaria sp.*), and tilapia (*Oreochromis sp.*). The sustainability of the species produced was assessed as the average of the feed sustainability score (0 protein based, 1 plant based; 0 imported feed, 1 local feed) and the biosecurity risk scored as species status (1 native, 0.75 introduced, or 0 invasive) and the pathogen and virus susceptibility (0 highly susceptible, 0.5 susceptible but preventative measures in place (biosecurity practices such as sterilization and wastewater treatment practices) (Table 11).

$X_t$ is the production potential of traditional Hawaiian fish ponds measured as the current number of remaining fishponds ($f_c$) compared to the historical 1990 reference ($f_r$) (DHM inc et al., 1990). The original fishpond data layer (Ogden Environmental Services, 1994) was modified by The Nature Conservancy and used in this analysis.

Data Gaps

- Kapuna knowledge on fishpond historical locations, practices, and production.
- Public perceptions of farmed seafood.
- Unknown total lbs. produced some years and some counties due to non-disclosure requirements.

## SENSE OF PLACE

This goal stresses the importance of the ocean and coastal areas for maintaining cultural practices, community wellbeing, and general sense of place. There were many valuable suggestions on how to measure Sense of Place including the use and knowledge of Hawaiian place names. Hawaiian names often reflect the activities, history, and the environment of the place. Unfortunately, there was no available and consistent way to measure the use of Hawaiian place names. This is a data gap and need that was identified during the development process for this goal. Another important component identified for sense of place is the connection or relationship that people have with the ocean and coastal areas. Therefore, as a proxy to measure Sense of Place, it was measured through activities that take place in each place, assessed as the participation rate in ocean and coastal activities.

$$X_{sp} = \frac{a_c}{a_r}$$

Table 11. Common mariculture species in Hawai‘i and their corresponding sustainability scores.

| Cultured Species | Species Name | Sustainable Feed (0=imported) | Feed Plant Based (0=protein based) | Susceptibility to Disease (0=highly susceptible) | Native (1), Introduced (0.5), Invasive (0) | Sustainability Score |
|---|---|---|---|---|---|---|
| Abalone | *Haliotus refens, Haliotus discus hanai* | 1 | 1 | 1 | 0.5 | 0.88 |
| Broodstock and juvenile shrimp | *Litopenaeus. vanamei, L. monodon, L. stylirostris* | 0 | 0 | 0 | 0.5 | 0.13 |
| Kahala (amberjack) | *Seriola dumerili* | 0 | 0 | 1 | 1 | 0.50 |
| Marine shrimp for food | *Penaeus vannamei* | 0 | 0 | 0 | 0.5 | 0.13 |
| Microalgae | *Spirulina sp, Hematococcus sp* | 1 | 1 | 1 | 1 | 1.00 |
| Seaweed/Limu | *Gracilaria sp* | 1 | 1 | 1 | 0.5 | 0.88 |
| Seed clams | *Mercenaria mercenaria* | 1 | 1 | 1 | 0.5 | 0.88 |
| Seed oysters and clams | *Crassostrea gigas, Venerupis Philippinarum, Crassostrea Sika-mea* | 1 | 1 | 1 | 0.5 | 0.88 |
| Tilapia | *Oreochromis sp* | 0 | 0 | 0 | 0 | 0.00 |

Where $a_c$ is the current resident participation rates in any ocean activity and $a_r$ is the reference participation rate, participation in any ocean activity at least once per month.

This information was collected across the state by the NOAA Coral Reef Conservation Program 2014 socioeconomic surveys of human use, knowledge, attitudes, and perceptions in Hawai'i (Gorstein et al., 2018). NOAA Socio-economic division began surveys to track the frequency of recreational activities in Hawai'i in 2014 and these surveys are planned to be repeated every 5-7 years. Since 2014 was the first year of the survey, there is not a trend score for this goal.

To find opportunities to connect to place and give back, go to Hawai'i Conservation Alliance's Conservation Connections http://www.conservationconnections.org.

Data Gaps

- Knowledge and records of Hawaiian place names including information on cultural practices.
- Community residence time or how long people live in the same community.
- Cultural site information including the total number of historical cultural and sacred sites.

## SUSTAINABLE TOURISM

This goal measures the balance between economic growth through tourism with management and preservation of natural resources and Hawaiian culture. The Sustainable Tourism goal model is the average of three indicators: economic ($r_a$ and $r_d$), sentiment ($s_c$) and environment ($p_c$).

$$X_T = \frac{\frac{r_a}{r_r} + \frac{r_d}{r_r}}{2} + \frac{s_c}{s_r} + \frac{p_c}{p_{30}}}{3}$$

where
$r_a$=current annual growth in visitor generated revenue (annual direct expenditures in 2009 real dollars))
$r_d$=current annual percent change in average daily visitor spending
$r_r$= reference annual growth rate for visitor generated revenue and average daily visitor spending of +2.5%
r ≥0.0% = 1
r<0.0% and r>-2.5% =0.9
r<-2.5% and r ≥ = -5.0% =0.8
$s_c$= current sentiment
$s_r$=reference sentiment target of 80%
$p_c$ =current percent of nearshore waters and priority watersheds protected
$p_{30}$ =30% percent of nearshore waters and priority watersheds protected

The mean of economic (visitor generated GDP and average visitor spending), sentiment (preservation of social and cultural values), and environment (protection of key habitats) were used to generate regional scores for sustainable tourism (Table 12).

Economic was scored based on two indicators of the economic contribution of visitors to Hawai'i: 1. Annual visitor expenditures and 2. Average daily visitor spending. These indicators reflect Hawai'i's economic reliance on visitor spending and recognize the stakeholder identified need to reduce the social and environmental impact of visitors while maintaining visitor generated revenue through increased visitor spending and while maintaining or decreasing the annual number of visitors. Visitor expenditures were adjusted by inflation by the implicit price deflator (DBEDT). The reference level for visitor contribution to economic growth was set at 2.5% annual growth rate (HTA, 2016). Visitor generated total expenditures was estimated to county level by weighting expenditures by the average daily number of visitors to each county (visitors defined as overnight stays (DBEDT). Average daily visitor spending was assessed as the annual percent change in visitor spending.

Sentiment was scored as the preservation of social and cultural values estimated though HTA visitor sentiment surveys (HTA, 2017). Three questions have been asked consistently and thus have time-series information. Responses to these questions were used to score the sentiment of residents on the benefits and impact of tourism in Hawai'i. The three questions were to rate the level of impact and agreement on: 1. Rate the overall impact of tourism on your family, 2. Tourism has brought more benefits than problems, and 3. The island is being run for the tourists at the expense of the local people. The three questions were normalized to a score from 0 to 100 with 100 being positive or agreement on positive impacts of tourism for residence of Hawai'i. Questions were averaged and scored to a reference value of 80 as set by the Hawai'i Tourism Authority as their target acceptance rate (HTA, 2017).

Environment was scored based on the protection of the natural environment including ocean areas (Marine Protected Areas, Fishery Replenishment Areas, and Community Subsistence Fishing Areas) and priority watersheds (watersheds that provide essential freshwater and protect key biodiversity). Environmental protection data comes from DLNR Division of Aquatic Resources Marine Manage Areas database (Hawai'i State Office of Planning) and DLNR Division of Forestry and Wildlife (Yuen, 2017). A reference rate of 30% nearshore areas effectively managed and priority watersheds protected by 2030 is based on the Governor's Sustainable Hawai'i Initiatives (State of Hawai'i) (https://governor.Hawaii.gov/sustainable-Hawaii-initiative).

Data Gaps

- While there are several education programs or information for visitors, data on park signage and education programs are not comprehensive or available state wide.
- An agreed upon plan for sustainable tourism, economic growth, and ecotourism has not been established by the State of Hawai'i.
- Among stakeholders it is unknown how much of the Tourism Accommodation Tax (TAT) goes back to environmental protection and restoration. Clarity and transparency on the TAT was recommended.

Table 12. Regional and yearly Sustainable Tourism component scores (economic, sentiment, and environmental indicators) and combined status score.

| Region | Year | Economic | Sentiment | Environment | Status |
|---|---|---|---|---|---|
| Hawai'i | 2012 | 100 | 73 | 42 | 72 |
| | 2013 | 100 | 70 | 42 | 71 |
| | 2014 | 100 | 69 | 42 | 69 |
| | 2015 | 95 | 68 | 42 | 65 |
| | 2016 | 85 | 68 | 42 | 70 |
| Maui Nui | 2012 | 100 | 73 | 72 | 82 |
| | 2013 | 100 | 70 | 72 | 81 |
| | 2014 | 100 | 69 | 72 | 80 |
| | 2015 | 85 | 68 | 72 | 75 |
| | 2016 | 100 | 68 | 72 | 80 |
| O'ahu | 2012 | 100 | 73 | 35 | 69 |
| | 2013 | 85 | 70 | 35 | 63 |
| | 2014 | 90 | 69 | 35 | 64 |
| | 2015 | 85 | 68 | 35 | 63 |
| | 2016 | 95 | 68 | 35 | 66 |
| Kaua'i & Ni'ihau | 2012 | 100 | 73 | 34 | 69 |
| | 2013 | 100 | 70 | 34 | 68 |
| | 2014 | 100 | 69 | 34 | 68 |
| | 2015 | 95 | 68 | 34 | 66 |
| | 2016 | 100 | 68 | 34 | 67 |

## BIODIVERSITY

The Biodiversity goal measures the conservation status of species based on two subgoals: Habitats ($X_{hab}$) and Species ($X_{spp}$).

$$X_{BD} = \frac{X_{hab} + X_{spp}}{2}$$

**Habitats**

The Habitats subgoal of Biodiversity measures the current extent and condition of ocean and coastal habitats ($H_c$) against a reference habitat extent and condition ($H_r$).

$$X_{hab} = \sum_{i=1}^{k} \left(\frac{H_c}{H_r}\right)$$

The habitat model assesses all habitats for which data are available to evaluate extent and condition, specifically: coral reefs, coastal wetlands and estuaries, beaches, and subtidal soft-bottom habitats. Status was calculated as the average of the condition estimates for each habitat present in a region. Condition was measured differently depending of the data available for the habitat and therefore was measured as the loss of habitat and/or percent degradation of remaining habitat.

Coral reefs

Coral reef extent was assessed from the cumulative impact mapping layers that combine hard bottom and coral reef habitats to a depth of 30 meters (Lecky, 2016). Coral reef condition was assessed through a coral reef index, which is a measure of coral reef health from combined indicators for coral cover, macroalgae (limu), coralline algae, and the ratio of calcifiers (corals and coralline algae) to non calcifiers (limu), coral mortality, juvenile coral density, and adult coral density. The coral reef index comes from the NOAA Hawai'i coral reef status report (NOAA Coral Reef Conservation Program and University of Maryland Center for Environmental Science). Trend in coral reef health is the recent (5 year) trend in coral cover and was assessed as the change in coral cover from 2011-2012 to 2016 surveys from the Main Hawaiian Islands (McCoy et al., 2017).

Beaches

Beach condition and trend data comes from Fletcher et al. 2012. Beach erosion is expected to increase with sea level rise and sea level rise acts as a large pressure on this goal. Beach extent is calculated as the total length of beach classifications 3, 4, and 5 from the National Oceanic and Atmospheric Administration Office of Response and Restoration Environmental Sensitivity Index (NOAA). Beach condition is the percent of beaches remaining stable (not eroding). The beach trend is the short-term erosion rate (past century) calculated from Fletcher et al. 2012. This data may be updated as USGS plans to assess the beach erosional rate every 5-10 years (Fletcher et al. 2012).

Soft Bottom
Nearshore soft bottom habitat extent was mapped to a depth of 30 meters (Lecky, 2016). The condition was measured as the proportion of soft bottom habitat that was not dredged. Dredging was defined as activity involving physically removing substrate with machinery typically to allow for safe passage of vessels (Lecky, 2016).

Coastal Wetlands
Coastal wetland extent was assessed from National Oceanic and Atmospheric Administration Coastal Change Analysis Program (NOAA C-CAP) data clipped to within 1 km inland from the coast to capture coastal wetlands extent. Wetland condition information comes from Van Rees and Reed (2014) and was modeled as the percent loss of historical coastal wetlands to an elevation of 304 meters. Trend in coastal wetlands was assessed as the difference in area from 2005 to 2010/2011 from NOAA CCAP wetlands extent within 1 km of the coastline.

Mangroves
Mangroves are invasive in Hawai'i and pose several negative ecological impacts (Allen, 1998), therefore they are not included in the goal models, but they are included as a pressure that is applied to Biodiversity, Sense of Place, and Food Provision.

Data Gaps
- Bioindicators of coral reef health are being developed by DAR and partners and will be used in future assessments of coral reef health.
- Additional habitats such as anchialine ponds, seamounts, deep sea coral reefs, estuaries, open ocean, and seagrass beds had limited information on condition and extent for all regions assessed and therefore were not included in the current assessment. These habitats are considered important and will be incorporated into future assessments as scientific data on these habitats becomes available.
- Need habitat and species information to update wetland condition, such as percent of invasive species or water quality data. More recent data (2005 -2010) on wetland extent to measure trends in extent is available from NOAA CCAP.
- Updated inventory on coastal wetlands and estuaries is currently being developed by the Hawai'i Department of Land and Natural Resources Division of Aquatic Resources this data will be used in the future to assess the condition of coastal wetlands.

**Species**
To assess species status, we combined information on local reef fish population status indicators and Endangered Species Act (ESA) status of marine mammals and turtles, seabirds and shorebirds, and coastal plants. We incorporated reef fish indicators as local indicators of reef fish species status.

$$X_{spp} = ESA + Fish$$

ESA status
Hawai'i does not have any listed extinct marine species, however Hawai'i is one of the species extinction capitals of the world due to the high presence of vulnerable endemic species. For a list of extinct species refer to the Bishop Museum Hawai'i's Extinct Species (http://hbs.bishopmuseum.org/endangered/extinct.html). Extant species were assigned an ESA listing score based on the severity of the listing status (Table 13).

Table 13. The score given for specific ESA status.

| ESA Status | Score |
|---|---|
| Non-concern or not listed | 1.0 |
| Vulnerable | 0.75 |
| Threatened | 0.5 |
| Endangered | 0.25 |

Marine Mammals & Turtles
Marine mammal and turtle species lists were from the Marine Biogeographic assessment for the Main Hawaiian Islands (Costa & Kendall, 2016). The status is based on the score given for each ESA category score (Table 13), with listing status from NOAA Hawai'i Marine Mammal List (NOAA Fisheries) and US Fish and Wildlife Service (US Fish and Wildlife Service) (Table 15).

Seabirds and Shorebirds
Seabirds and shorebirds were identified in the Marine Biogeographic assessment for the Main Hawaiian Islands (Costa & Kendall, 2016). There are at least 22 species of seabirds that breed in the Hawaiian Islands. Twenty of these species breed in the Main Hawaiian Islands (Costa & Kendall, 2016). Five shorebirds that are found in the Main Hawaiian Islands were added to the assessment (US Fish and Wildlife Service). Status was determined by ESA listings and from the State of the Birds yellow and red watch lists (US Fish and Wildlife Service; Rosenberg et al., 2014) and weighted by listing rank (Table 14; Table 16).

Table 14. Seabird and shorebird score weighting based on ESA status (https://www.fws.gov/endangered/) and State of the Birds yellow and red watch lists (http://www.stateofthebirds.org/2014/extinctions/watchlist.pdf).

| ESA Status | Score |
|---|---|
| Non-concern or not listed | 1.0 |
| Yellow Watch List | 0.7 |
| Threatened | 0.5 |
| Endangered or Red Watch List | 0.25 |

Coastal Plants
Species list and status of coastal plants were sourced from Merlin 1999 and the USFWS (https://ecos.fws.gov/ecp/) (Table 17). Species status was scored using ESA category score (Table 13).

Fish
The reef fish indicator was assessed as the average of 3 components: Reef Fish Biomass, Reef Fish Sustainability, and Reef Fish Predators (NOAA Coral Reef Conservation Program and University of Maryland Center for

Table 15. The ESA status of Hawai'i's marine mammals and turtles.

| Common Name | Species Name | ESA Status |
|---|---|---|
| Blainville's beaked whale | *Mesoplodon densirostris* | NC |
| Blue whale | *Balaenoptera musculus musculus* | E |
| Bryde's whale | *Balaenoptera edeni* | NC |
| Common bottlenose dolphin | *Tursiops truncatus truncatus* | NC |
| Cuvier's beaked whale | *Ziphius cavirostris* | NC |
| Dwarf sperm whale | *Kogia sima* | NC |
| False killer whale | *Pseudorca crassidens* | E |
| Fin whale | *Balaenoptera physalus physalus* | E |
| Fraser's dolphin | *Lagenodelphis hosei* | NC |
| Green | *Chelonia mydas* | T |
| Hawaiian monk seal | *Neomonachus schauinslandi* | E |
| Hawksbill | *Ertmochelys imbricata* | E |
| Humpback whale | *Megaptera novaeangliae* | E |
| Killer whale | *Orcinus orca* | NC |
| Leatherback | *Dermochelys cariacea* | E |
| Loggerhead | *Caretta caretta* | E |
| Longman's beaked whale | *Indopacetus pacificus* | NC |
| Melon-headed whale | *Peponocephala electra* | NC |
| Minke whale | *Balaenoptera acutorostrata scammoni* | NC |
| North Pacific right | *Lissodelphis borealis* | NC |
| Olive Ridley | *Lepidochelys olivacea* | T |
| Pantropical spotted dolphin | *Stenella attenuata attenuata* | NC |
| Pygmy killer whale | *Feresa attenuata* | NC |
| Pygmy sperm whale | *Kogia breviceps* | NC |
| Risso's dolphin | *Grampus griseus* | NC |
| Rough-toothed dolphin | *Steno bredanensis* | NC |
| Sei whale | *Balaenoptera borealis borealis* | E |
| Short-finned pilot whale | *Globicephala macrorhynchus* | NC |
| Sperm whale | *Physeter macrocephalus* | E |
| Spinner dolphin | *Stenella longirostris longirostris)* | NC |
| Striped dolphin | *Stenella coeruleoalba* | NC |

Table 16. Seabird and shorebird species for the Main Hawaiian Islands with ESA (E= endangered, T= threatened) or State of the Birds Status (Y=yellow watch list; R=red watch list).

| Type | Common Name | Hawaiian Name | Species Name | Status |
|---|---|---|---|---|
| Seabird | Band-rumped storm-petrel | | Oceanodroma castro | E |
| Seabird | Black-footed albatross | | Phoebastria nigripes | Y |
| Seabird | Black noddy | | Anous stolidus pileatus | Y |
| Seabird | Black-winged petrel | | Pterodroma nigripennis | NC |
| Seabird | Blue noddy | | Procelesterna cerulean | Y |
| Seabird | Brown booby | ʻA | Sula leucogaster | Y |
| Seabird | Brown noddy | Noio koha | Anous stolidus | NC |
| Seabird | Bulwer's Petrel | ʻOu | Bulweria bulwerii | Y |
| Seabird | Christmas shearwater | | Puffinus nativitatis | Y |
| Seabird | Cook's Petrel | | Pterodroma cookii | NC |
| Seabird | Gray-backed tern | Pokalakla | Onychonprion lunatus | Y |
| Seabird | Great frigatebird | ʻIwa | Fregata minor | Y |
| Seabird | Hawaiian black noddy | | Anous minutus melanogenys | Y |
| Seabird | Hawaiian petrel (dark-rumped petrel) | ʻUaʻu | Pterodroma phaeopygia sandwichensis | E(R) |
| Seabird | Juan Fernandez petrel | | Pterodroma externa | NC |
| Seabird | Laysan albatross | Moli | Phoebastria immutabilis | Y |
| Seabird | Masked Booby | ʻA | Sula dactylatra | Y |
| Seabird | Mottled petrel | | Pterodroma inexpectata | NC |
| Seabird | Newell's shearwater | ʻAʻo | Puffinus newelli | E |
| Seabird | Red-footed booby | ʻA | Sula sula | NC |
| Seabird | Red-tailed tropicbird | | Phaethon rubricauda | Y |
| Seabird | Sooty tern | ʻEwaʻewa | Onychoprion fuscata | NC |
| Seabird | Wedge-tailed shearwater | ʻUaʻu kani | Puffinus pacificus | NC |
| Seabird | White or ferry tern | Manu-o-ku | Gygis alba | NC |
| Seabird | White-tailed tropic bird | | Phaethon lepturus | Y |
| Shorebird | Bristle-thighed curlew | Kioea | Numenius tahitiensis | NC |
| Shorebird | Pacific golden plover | Kolea | Pluvialis fulva | NC |
| Shorebird | Sanderling | Hunakai | Calidris alba | NC |
| Shorebird | Ruddy turnstone | Akekeke | Arenaria interpres | NC |
| Shorebird | Wandering tattler | ʻŪlili | Heteroscelus incanus | NC |

Table 17. List of coastal plants and ESA status.

| Common Name | Hawaiian Name | Species name | ESA Status |
|---|---|---|---|
| Beach spurge | Koko, ʻakoko | *Chamaesyce degeneri* | NC |
| | ʻĀkia, kauhi | *Wikstroemia spp* | NC |
| | Ahuawa | *Mariscus javanicus* | NC |
| | Akaakai | *Schoenoplectella tabernae-montani* | NC |
| | Alena | *Boerhavia repens* | NC |
| | Degener's ʻakoko | *Euphorbia degeneri* | V |
| Dwarf naupaka | Dwarf naupaka | *Scaevola coriacsea* | E |
| Pandanus | Hala/Pu hala | *Pandanus tectorius* | NC |
| | Hau | *Taliparitі tiliaceus* | NC |
| | Hinahina | *Heliotropium anomalum* | NC |
| Hawaiian Nama | Hinahina Kahakai | *Nama sandwicensis* | V |
| Moonseed | Huehue | *Cocculus orbiculatus* | NC |
| | Hunakai | *Ipomoea imperati* | NC |
| | Kalo | *Colocasia esculenta* | NC |
| Alexandrian Laurel | Kamai | *Calophyllum inophyllum* | NC |
| | Kaunaʻoa | *Cuscuta sandwichiana* | NC |
| | Kāwelu, ʻEmoloa | *Eragrostis variabilis* | NC |
| | Kaʻena ʻakoko | *Euphorbia celastroides var. kaenana* | E |
| Ivy-leaved morning glo-ry | Koaliʻai | *Ipomoea cairica* | NC |
| Coastal morning glory | Koaliʻawa | *Ipomoea littoralis* | NC |
| Indian morning glory | Koaliʻawa | *Ipomoea indica* | NC |
| | Makaloa | *Cyperus laevigatus* | NC |
| | Mauʻu/ʻAkiʻaki | *Fimbristylis cymosa subsp. Spathacea* | NC |
| | Mauʻu/ʻAkiʻaki | *Fimbristylis cymosa subsp. Umbellato-capitata* | NC |
| Hawaiian Cotton | Maʻo | *Gossypium tomentosum* | V |
| | Milo | *Thespesia populnea* | NC |
| Bastard sandalwood | Naio | *Myoporum sandwicense* | NC |
| Beach sandalwood | ʻIliahialoʻe | *Santalum ellipticum* | V |
| Beach pea | Nanea | *Vigna marina* | NC |
| Beach Naupaka | Naupaka kahakai | *Scaevola sericea* | NC |
| | Nehe | *Melanthera integrifolia, Lipochaeta integrifolia* | V |
| | Nehe | *Lipochaeta succulenta* | NC |
| | Neke Fern | *Cyperus interruptus* | NC |
| Seaside heliotrope | Nena/Kipukai | *Heliotropium curassavicum* | NC |
| Coconut palm | Niu | *Cocos nucifera* | NC |
| Puncture vine | Nohu | *Tribulus cistoides* | NC |
| | Paʻuohiʻiaka | *Jacquemontia ovalifolia* | NC |

Table 17. List of coastal plants and ESA status (continued).

| Common Name | Hawaiian Name | Species name | ESA Status |
|---|---|---|---|
| Beach vitex | Pohinahina | *Vitex rotundifolia* | NC |
| Beach morning glory | Pohuehue | *Ipomoea pes-caprae* | NC |
| | Pōpolo | *Solanum nelsonii* | E |
| Caper bush, | Pua pilo or Maiapilo | *Capparis sandwichiana* | V |
| Prickly poppy | Pua kala | *Aregemone glauca* | NC |
| | Puukaa | *Cyperus trachysanthos* | E |
| Schiedea | | *Schiedea globosa* | V |
| | Uki | *Cladium jamaicense* | NC |
| Water Hyssop | ʻAeʻae | *Bacopa monnieri* | NC |
| Seashore rushgrass | ʻAkiʻaki | *Sporobolus virginicus* | NC |
| East Maui ʻAkoko | ʻAkoko | *Euphorbia celastroides var. laechiensis* | E |
| Sea purslane | ʻAkulikuli | *Sesuvium portulacastrum* | NC |
| | ʻAnaunau | *Lepidium bedentatum* | V |
| | ʻEnaʻena | *Psuedognaphalium sand-wicensium* | NC |
| | ʻIhi | *Portulaca molokiniensis* | E |
| Pigweed | ʻIhi | *Portulaca lutea* | NC |
| Hairy Purslane | ʻIhi | *Portulaca villosa* | E |
| Kilauea Portulaca | ʻIhi makole | *Portulaca sclerocarpa* | E |
| | ʻIlima | *Sida fallax* | NC |
| | ʻOhai | *Sesbania tomentosa* | E |
| | ʻOhelo kai | *Lycium sandwicense* | NC |
| | ʻŌhiʻa lehua | *Metrosideros polymorpha* | NC |
| | ʻŪlei, eluehe, uʻulei | *Osteomeles anthyllidifolia* | NC |
| | Wiliwili | *Erythrina sandwicensis* | NC |
| | ʻUhaloa/Hiʻaloa | *Waltheria indica* | NC |

Environmental Science). Reef Fish Biomass measures the mean biomass of all reef fishes other than sharks and jacks derived from underwater visual surveys of <30m hard bottom habitats. Survey biomass per location is compared against a meaningful local baseline (to account for inherent environmental and habitat differences among locations). High scores therefore represent populations that are close to their natural carrying capacity. Reef Fish Sustainability represents an index of mean size for targeted reef fish species relative to their size at first maturity. High scores therefore represent assemblages where there are still many of large individuals of targets species, those large fishes being particularly important components of the breeding stock. The Reef Fish Predators indicator is made up of 2 components: 'reef sharks' and 'other reef piscivores' with data taken respectively from towed-diver and point-count surveys by divers. High scores represent locations where upper trophic level fishes are still a conspicuous and ecologically important component of the reef ecosystem.

Data Gaps

- Population assessments are not available for every marine species and tend to be focused on iconic and resource species.
- Eels and other cryptic species are not accurately assessed in standard marine monitoring surveys and are not represented in the reef fish indicator.

## COASTAL PROTECTION

This goal aims to assess the amount of protection provided by marine and coastal habitats against flooding and erosion to coastal areas. The condition of each habitat was calculated with various methods depending on data availability, which are mostly based on coverage area. Habitats that are included and provide substantial coastal protection are: beaches, coral reefs, and wetlands. A score of 100 would indicate that these habitats are all still intact or have been restored to their reference conditions.

$$X_{CP} = \sum_{i=1}^{k} (\frac{C_c}{C_r})$$

C is the current (c) condition and reference (r) habitat condition.

Coral reefs

Coral reef extent was assessed from the cumulative impact mapping layers that combine hard bottom and coral reef habitats to a depth of 30 meters (Lecky, 2016). Coral reef condition was assessed through a coral reef index, which is a measure of coral reef health from combined indicators for coral cover, macroalgae (limu), coralline algae, and the ratio of calcifiers (corals and coralline algae) to non calcifiers (limu), coral mortality, juvenile coral density, and adult coral density. The coral reef index comes from the NOAA Hawai'i coral reef status report (NOAA Coral Reef Conservation Program and University of Maryland Center for Environmental Science). Trend in coral reef health is the recent (5 year) trend in coral cover and was assessed as the change in coral cover from 2011-2012 to 2016 surveys from the Main Hawaiian Islands (McCoy et al., 2017).

Beaches

Beach condition and trend data comes from Fletcher et al. 2012. Beach erosion is expected to increase with sea level rise and sea level rise acts as a large pressure on this goal. Beach extent is calculated as the total length of beach classifications 3, 4, and 5 types of beaches from the National Oceanic and Atmospheric Administration Office of Response and Restoration Environmental Sensitivity Index (NOAA). Beach condition is the percent of beaches remaining stable (not eroding). The beach trend is the short-term erosion rate calculated from Fletcher et al. 2012. This data may be updated as USGS plans to assess the beach erosional rate every 5-10 years (Fletcher et al. 2012).

Wetlands

Wetlands are classified based on soil saturation, percent of herbaceous vegetation, trees and shrubs, locality (riverine), and salinity. Along with providing coastal protection, wetlands are important habitats which are critical habitats for many endemic and endangered plants and animals. Pressures to wetlands include invasive species (including mangroves), land development, and land-based sources of pollution. Coastal wetland extent was assessed from National Oceanic and Atmospheric Administration Coastal Change Analysis Program (NOAA C-CAP) data layer clipped to within 1 km inland from the coast to capture coastal wetlands extent. All estuary categories were included in this assessment that were within 1km of the coastline as these habitats within 1km of the shoreline will mitigate against flooding and wave inundation. Wetland condition information comes from Van Rees and Reed (2014) and was modeled as the percent loss of historical coastal wetlands to an elevation of 304 meters. Trend in coastal wetlands was assessed as the difference in area from 2005 to 2010/2011 NOAA CCAP wetlands extent within 1 km of the coastline (NOAA Office for Coastal Management).

Mangroves

While mangroves are considered unique and integral ecosystems in their native range they can be a huge threat to areas where they are introduced and invasive, such as Hawai'i. While they do offer coastal protection, we did not include them in this assessment as they are considered to do more harm than good. Mangroves have especially large impacts to native biodiversity and traditional Hawaiian fishponds (loko i'a) (Allen, 1998). Removal efforts are underway to remove and clear mangroves and restore native estuaries and fishponds.

Data Gaps

- Sand dune habitats are also important for coastal protection and will be incorporated with beach habitats once data becomes available on their extent, condition, and trend.
- Future models could be improved by incorporating estimates of shoreline protective ability based on slope or shoreline relief or aspect ratios.
- Scientific analysis or information on the protective ability or importance of each habitat for coastal protection in Hawai'i.

- Updated inventory on coastal wetlands and estuaries is currently being developed by the Hawai'i Department of Land and Natural Resources Division of Aquatic Resources this data will be used in the future to assess the condition of coastal wetlands.

## LIVELIHOODS & ECONOMIES

The goal includes the two subgoals: Livelihoods ($X_{liv}$) and Economy ($X_{eco}$).

$$X_{liv} = \frac{\frac{\sum_k j_{c,k}}{\sum_k j_{r,k}} + \sum_k \frac{g_{c,k}}{g_r} * w}{2}$$

Data on ocean livelihoods and economies comes from the NOAA ENOW for employment (jobs), wages, and revenue by ocean sector (ENOW, 2017). Sectors include: Marine Construction, Living Resources, Ship and Boat Building, Tourism and Recreation, and Marine Transportation (Table 18). Self-employed and state employed data sets were aggregated and summarized by county. However, when aggregated to county some of the information was undisclosed therefore this data represents a conservative estimate of ocean livelihoods and economies. Industry multipliers were applied to represent indirect benefits (Table 19).

### Livelihoods

$$X_{liv} = \frac{\frac{\sum_k j_{c,k}}{\sum_k j_{r,k}} + \sum_k \frac{g_{c,k}}{g_r} * w}{2}$$

Livelihoods was measured as the mean of ocean jobs and wages measured as the current number of jobs ($j_c$) per marine and ocean sector (k) in relation to a reference year ($j_r$; 5 year moving window) and the sector average wage referenced to the county average wage and weighted by the proportion of jobs per sector (w). Current year (c) is the most recent year with available data (2013). Data on ocean sector employment and wage comes from NOAA Office for Coastal Management (ENOW, 2017) and was adjusted by state unemployment rate (DBEDT, 2016).

### Economies

$$X_{eco} = \frac{\sum_{k=1}^{n} e_{c,k}}{\sum_{k=1}^{n} e_{r,k}}$$

Economies model is composed of a single component, revenue, where e is the total adjusted revenue generated directly and indirectly from each marine and ocean sector (k), at current (c), and reference (r), time points. Data on ocean revenue comes from NOAA Office for Coastal Management (ENOW, 2017).

Data Gaps

- Some sectors are not well represented in Livelihoods and Economies, such as pro-surfers and marine and ocean scientists.

Table 18. Ocean livelihood and economy sectors (ENOW, 2017).

| Sector | Industry |
|---|---|
| Ship and Boat Building | Boat Building and Repair |
| | Ship Building and Repair |
| Tourism and Recreation | Boat Dealers |
| | Eating and Drinking Places |
| | Hotels and Lodging |
| | Marinas |
| | Recreational Vehicle Parks and Campsites |
| | Scenic Water Tours |
| | Sporting Goods |
| | Amusement and Recreation Services |
| | Zoos, Aquaria |
| Living Resources | Fish Hatcheries and Aquaculture |
| | Fishing |
| | Seafood Processing |
| | Seafood Markets |
| Marine Construction | Marine Related Construction |
| Marine Transportation | Deep Sea Freight |
| | Marine Passenger Transportation |
| | Marine Transportation Services |
| | Search and Navigation Equipment |
| | Warehousing |

Table 19. Industry multipliers for indirect jobs and revenue (DBEDT, 2013). Sectors were assigned a value of 1.00 if industry multipliers were not available for the sector.

| Ocean Sector | Jobs | Revenue |
|---|---|---|
| Tourism & Recreation | 1.27 | 1.32 |
| Living Resources | 1.76 | 1.58 |
| Marine Construction | 1.00 | 1.00 |
| Ship & Boat Building | 1.00 | 1.00 |
| Marine Transportation | 1.69 | 1.63 |

# DATA LAYERS

This section lists all the data layers and how they were applied to each goal for the 2018 Hawai‘i Ocean Health Index. Data layers used in each goal are listed in Table 20. Pressure categories and how each pressure layer was applied to each goal can be found in Table 21 and Table 22. Resilience categories and how each resilience layer was applied to each goal can be found in Table 23 and Table 24. The full data used in the assessment and links to the original data source can be found at ohi-science.org/mhi.

Looking from mauka to makai, Kaua‘i. Photo:Conservation International photo by Luana Luna

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index.

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Coastal Protection | beach condition | The condition of coastal habitats measured as the percent of beaches eroding per region. | Fletcher et al. (2012) |
| Coastal Protection | beach extent | Beach extent was calculated from the from ESI GIS layer (Beaches (3,4,5 classifications)). The data units are in km not km2 like other habitats. | NOAA Hawaii ESI |
| Coastal Protection | beach trend | The average short-term erosion rate of beaches, estimated at -0.06 m per year. | Fletcher et al. (2012) |
| Coastal Protection | coastal wetland condition | Wetland condition was calculated based on percent of historical extent. | Van Rees and Reed (2014) |
| Coastal Protection | coastal wetland extent | The area of coastal wetlands (within 1 km of the coastline). | NOAA Office of Coastal Management |
| Coastal Protection | coastal wetland trend | The annual percent change in wetland extent based on NOAA C-CAP data comparisons from 2005 to 2010/2011 clipped to 1 km from the shoreline. | NOAA Office of Coastal Management |
| Coastal Protection | reef condition | The benthic condition of coral reefs assessed through a combination of variables including percent coral cover, percent macroalgae cover, demog-raphy, and mortality. | NOAA Coral Reef Conservation Program and Uni-versity of Mary-land Center for Environmental Science |
| Coastal Protection | reef extent | The hardbottom extent out to 80 meters modified from NOAA habitat maps. | Lecky (2016) |
| Coastal Protection | reef trend | The estimated change in percent coral cover calculated from the past 5 years of available monitoring data from NOAA Ecosystem Program. | McCoy et al. (2017) |
| Economies | ocean and coastal revenue | The revenue generated per ocean sector for each county. | ENOW (2017) |
| Habitats | beach condition | The condition of coastal habitats measured as the percent of beaches eroding per region. | Fletcher et al. (2012) |
| Habitats | beach extent | Beach extent was calculated from the from ESI GIS layer (Beaches (3,4,5 classifications)). The data units are in km not km2 like other habitats. | NOAA Hawaii ESI |
| Habitats | beach trend | The average short-term erosion rate of beaches, estimated at -0.06 m per year. | Fletcher et al. (2012) |
| Habitats | coastal wetland condition | Wetland condition was calculated based on percent of historical extent. | Van Rees and Reed (2014) |
| Habitats | coastal wetland extent | The area of coastal wetlands (within 1 km of the coastline). | NOAA Office of Coastal Management |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Habitats | coastal wetland trend | The annual percent change in wetland extent based on NOAA C-CAP data comparisons from 2005 to 2010/2011 clipped to 1 km from the shoreline. | NOAA Office of Coastal Management |
| Habitats | reef extent | The hardbottom extent out to 80 meters modified from NOAA habitat maps. | Lecky (2016) |
| Habitats | reef trend | The estimated change in percent coral cover calculated from the past 5 years of available monitoring data from NOAA Ecosystem Program. | McCoy et al. (2017) |
| Habitats | soft bottom condition | The percent of soft bottom habitat not impacted by dredging. | Lecky (2016) |
| Habitats | soft bottom extent | Soft bottom habitat extent was de-rived from the cumulative impact habitat maps. | Lecky (2016) |
| Habitats | soft bottom trend | Trend was not evaluated for soft bottom habitats. | |
| Livelihoods | Hawaii average wage | The Hawaii average annual wage by county | DBEDT |
| Livelihoods | ocean and coastal jobs | The total number of jobs per ocean sector for each county. | ENOW (2017) |
| Livelihoods | ocean and coastal sector mean wages | The mean wage per ocean sector by county | ENOW (2017) |
| Livelihoods | resident population | The number of residents per county. | DBEDT |
| Livelihoods | unemployment | The unemployment rate. | DBEDT |
| Livelihoods | workforce | The total number of jobs per county. | DBEDT |
| Mariculture | mariculture yield | Production of shellfish and food fish from mariculture facilities | US DOA (2015) |
| Mariculture | number of fish-ponds | The current number of fishponds. | Ogden Environmental Services (1994) |
| Mariculture | number of fish-ponds in 1990 survey | The number of fishponds per county from the 1990 assessment. | DHM inc et al. (1990) |
| Mariculture | operations | The number of mariculture operators. | USDA |
| Nearshore Fisheries | resource | Resource condition was measured through a reef fish indicator. The reef fish indicator is the average of 3 components (Reef Fish Biomass, Reef Fish Sustainability, and Reef Fish Predators). | NOAA Coral Reef Conservation Program and University of Maryland Center for Environmental Science |
| Offshore Fisheries | bottom fisheries commer-cial catch | Bottomfish catch (lbs) reported in the commercial fishery. | DLNR DAR |
| Offshore Fisheries | commercial coastal pelagic fisheries catch | Coastal pelagic fish catch (lbs) reported in the commercial fishery. | DLNR DAR |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Offshore Fisheries | pelagic fisheries commercial catch | Pelagic fish catch (lbs) reported in the commercial fishery. | DLNR DAR |
| Offshore Fisheries | sustainability of bottomfish fishery | Bottomfish stock assessment. | Langseth et al. (2018) |
| Offshore Fisheries | sustainability of pelagic fishery | Pelagic (tuna and swordfish) stock assessments. | WCPFC; ISC (2017) |
| Pressure | aquarium fishing | The pressure on the nearshore from aquarium fishing estimated as the reported take to DAR, standardized to km2 of hardbottom habitat. | Wedding et al. (2017); OTP |
| Pressure | commercial fishery high bycatch | The ratio of catch to bycatch for the tuna fishery (deep set longlines). | Benaka et al. (2013) |
| Pressure | commercial fishery low bycatch | The ratio of catch to bycatch for swordfish fishery (shallow set longlines). | Benaka et al. (2013) |
| Pressure | coral bleaching | Mean degree heating weeks (DHW) for nearshore areas (with in 10 km of the coastline), with coral bleaching expected after 4 DHW. Scores of 1 indicate that coral bleaching is expected or occurred. | NOAA Satellite and Information Service |
| Pressure | direct impacts from humans (trampling, recreation, etc) | InVEST recreation model was run statewide at 1 km resolution for the years 2005 - 2014. This model uses publicly visible geotagged photos posted to the photo-sharing website Flickr to calculate the annual average number of photo users per day per grid cell. This is a proxy for direct human impact to nearshore and coastal environments. | Wedding et al. (2017); OTP |
| Pressure | economic loss from sea level rise | The estimated economic loss from a predicted near future 3.2 ft. sea level rise. | Hawai'i Climate Change Mitigation and Adaptation Commission |
| Pressure | forest health | The percent of native forests dominated by non-native species. | LANDFIRE (2008) |
| Pressure | habitat destruction caused by coastal engineering | Coastal engineering consisted of shoreline armoring structures (e.g., seawalls, revetments, groins, break waters), artificial land (i.e., land fill), and piers. | Wedding et al. (2017); OTP |
| Pressure | habitat destruction from dredging | Dredging was defined as activity involving physically removing substrate with machinery typically to allow for safe passage of vessels. | Wedding et al. (2017); OTP |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai‘i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Pressure | habitat destruction of benthic structures | Benthic structures were defined as manmade features in the offshore environment that disrupt benthic habitat and include moored buoys, channel markers, offshore cables and pipelines. | Wedding et al. (2017); OTP |
| Pressure | invasive species (algae and mangroves) | Represents presence-only of invasive algae species in nearshore waters and mangroves along the shoreline. | Wedding et al. (2017); OTP |
| Pressure | land-based sedi-ment ex-port to nearshore water | Mean sediment load to nearshore waters (1.5km). | Wedding et al. (2017); OTP |
| Pressure | land-based source of pol-lution from agriculture and golf courses | The proxy for agricultural and land-scaping runoff (nutrients from fertilizers; chemicals like pesticides and herbicides), calculated as the area of agricultural land and golf courses by watershed with a maximum stressor level set at 10% of watershed area. | Wedding et al. (2017); OTP |
| Pressure | land-based source of pollution from urban runoff | A proxy for nutrient and chemical pollution measured as the percent of impervious surfaces per watershed with a maximum stressor level set at 10% of watershed area. | Wedding et al. (2017); OTP |
| Pressure | land-based source of pollution nitrogen | Mean nitrogen flux from on-site disposal systems (OSDS) into near-shore waters (1.5 km from shore). | Wedding et al. (2017); OTP |
| Pressure | marine debris | The State of Hawaii Division of Aquatic Resources aerial imagery of marine debris from 2015. | Wedding et al. (2017); OTP |
| Pressure | ocean acidification | Ocean acidification pressure scaled using biological thresholds. | Halpern et al. (2008) |
| Pressure | proxy for intertidal habitat destruction | The coastal population density (with in 25 mi from shore) as a proxy for intertidal habitat destruction, calculated as resident population per km of shoreline and standardized by maxi-mum regional score. | DBEDT |
| Pressure | reef fishing catch | The modeled reef fish catch from com-mercial and recreational fishery taking into account shoreline accessi-bility. | Wedding et al. (2017); OTP |
| Pressure | sea level rise | The estimated pressure on coastal areas from a 3.2 ft. prediction of the near future sea level rise. | Hawai‘i Climate Change Mitiga-tion and Adapta-tion Commission |
| Pressure | sea surface tem-perature | The difference in the annual mean sea surface temperature for Hawaii EEZ waters compared to the 20th century mean sea surface temperature. | NOAA: National Centers for Environmental Information |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Pressure | ship-based groundings | To represent the risk of ship groundings and wrecks to coastal waters, the footprint of this ship traffic layer was clipped to 9 m depth. | Wedding et al. (2017); OTP |
| Pressure | ship-based pollution | Ship traffic layer was used as a proxy for ship-based pollution. | Wedding et al. (2017); OTP |
| Pressure | terrestrial aquaculture | The environmental footprint of terrestrial aquaculture facilities. | Wedding et al. (2017); OTP |
| Pressure | uv radiation | The modeled UV radiation based on Erythemal UV Irradiance data provided by GES DISC. | Halpern et al. (2008) |
| Pressure | visitors participating in kayaking | The number of visitors per km of coastline that kayak or canoe per county standardized to the regional maximum which occurs on Oahu. | HTA (2015) |
| Pressure | visitors participating in snorkeling or scuba diving | The number of visitors per km of coastline that use thrill craft per county standardized to the regional maxi-mum which occurs on Oahu. | HTA (2015) |
| Pressure | visitors participating in surfing | The number of visitors per km of coastline that surf or bodyboard per county standardized to the regional maximum which occurs on Oahu. | HTA (2015) |
| Pressure | visitors participating in swimming | The number of visitors per km of coastline that swim and go to the beach per county standardized to the regional maximum which occurs on Oahu. | HTA (2015) |
| Pressure | visitors participating in thrill craft | The number of visitors per km of coastline that whale watch per county standardized to the regional maximum which occurs on Oahu. | HTA (2015) |
| Pressure | visitors participating in whale watching | The number of visitors per km of coastline that whale watch per county standardized to the regional maximum which occurs on Oahu. | HTA (2015) |
| Pressure | weakness of governance | The Inverse of World Governance Indicators (WGI) calculated as the six combined scores. | Halpern et al. (2008) |
| Pressure | weakness of social progress | The inverse of the Social Progress Index scores. | Halpern et al. (2008) |
| Resilience | access to shoreline | Estimated fishery access land-based fishing based on shoreline access (marine managed areas and military areas, roads, and steepness of shoreline). | Wedding et al. (2017); OTP |
| Resilience | CITES signatories | The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signatories. | Halpern et al. (2008) |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Resilience | coastal MPAs fisheries resilience | The ratio of management areas to total coastal area within 3nm. | Office of Planning (n.d.) |
| Resilience | climate change adaptation plans | The percent of county/community plans that include a climate change adaptation (CCA) component. Target is to reach 100% by 2030. | Coastal Zone Management Pro-gram (2013) |
| Resilience | EEZ MPAs habitat resiience | The ratio of management areas (BRFA, Longline, Monument) to the total ocean area with the EEZ and di-vided into OHI regions. | Office of Planning |
| Resilience | experience of visitors | The percent of visitors that report hav-ing an excellent experience. | DBEDT (2016) |
| Resilience | fishpond restoration suport | The percent of county fishponds that receive technical assistance from the State. | OP CZM; Coastal Zone Management Program (2013) |
| Resilience | habitat health | The scores from the habitats subgoal of biodiversity are used as resilience for Livelihoods and Economies and the Sustainable Tourism goals. | HTA (2015) |
| Resilience | increase in shoreline access points | The increase in shoreline access points from the ORMP. Reference value is the mean number of access points added over the last five years. | OP CZM; Coastal Zone Manage-ment Program (2013) |
| Resilience | makai watch trainings | The mean number of DLNR led Makai Watch trainings to communi-ties to sup-port nearshore fisheries pono fishing practices and regula-tions. | DLNR DO-CARE; OP CZM; Coastal Zone Manage-ment Pro-gram (2013) |
| Resilience | Mo'omeheu - Value of History and Culture | The preservation of culture. Mo'omeheu - Value of History and Culture. | Office of Hawai-ian Affairs |
| Resilience | recycled wastewater | The percent of wastewater that is recycled annually. Target is 100%. | OP CZM; Coastal Zone Manage-ment Program (2013) |
| Resilience | Social Progress Index | The Social Progress Index scores. | Halpern et al. (2008) |
| Resilience | State New Econ-omy Index | The State New Economy Index uses 25 indicators to measure the extent to which state economies are knowledge-based, globalized, entre-preneurial, IT-driven, and innovation-oriented. | The Information Technology and Innovation Foundation (2014) |
| Resilience | strength of governance | The World Governance Indicators (WGI) six combined scores. | Halpern et al. (2008) |
| Resilience | watershed partnerships | The ratio of watershed partnerships to historic native forest extent. | HWAP; Office of Planning |

Table 20. Data layers, description, and reference for each goal and subgoal, pressure, and resilience dimension of the Hawai'i Ocean Health Index (continued).

| Targets | Layer | Description | Reference |
|---|---|---|---|
| Resilience | watersheds protected | The percent of priority watersheds that are fenced to protect against invasive animals. | Yuen (2017) |
| Sense of Place | participation in recreational activities | The NOAA Coral Reef Conservation Program 2014 socioeconomic surveys of human use, knowledge, attitudes, and perceptions in Hawaii. | Gorstein et al. (2018) |
| Species | ESA coastal plant status | The list of Hawaii coastal plant species and status of coastal sand-dune plants scored based on ESA status. | Merlin (1999); US Fish and Wildlife Service |
| Species | ESA marine mammal status | The list of marine mammals found in Hawaii and status of marine mammals scored based on ESA status. | NOAA Fisheries; Costa and Kendall (2016) |
| Species | ESA seabird and coastal bird status | The list of seabirds and coastal birds scored based on ESA status and State of the Birds watch lists. | Rosenberg et al. (2014); US Fish and Wildlife Service |
| Species | fish indicator | The reef fish indicator is the average of 3 components (Reef Fish Biomass, Reef Fish Sustainability, and Reef Fish Predators). | NOAA Coral Reef Conservation Program and University of Maryland Center for Environmental Science |
| Sustainable Tourism | average daily visitor spending | Annual percent change in daily visitor spending | DBEDT |
| Sustainable Tourism | environmental protection | The percent of nearshore areas priority watersheds protected in reference to Hawaii Sustainability Initiatives (30 by 30 targets). This data may change as the State DLNR Division of Aquatic Resources develops the 30 by 30 initiative. | Office of Planning |
| Sustainable Tourism | resident sentiment | The Hawaii Tourism Authority's survey on resident sentiment to tourism. | HTA (2017); HTA evaluation and performance measures |
| Sustainable Tourism | visitor contributed GDP | Visitor generated GDP with a target set by the Hawaii Tourism Authority of 2.5% annual growth. | HTA |

Table 21. Pressure layers and categories.

| Data Layer | Short Name | Category | Subcategory |
|---|---|---|---|
| terrestrial aquaculture | sp_aquacul_terrest | ecological | alien_species |
| invasive species (algae and mangroves) | sp_ispp_a_m | ecological | alien_species |
| ocean acidification | cc_acid | ecological | climate change |
| sea level rise | cc_sealevel | ecological | climate change |
| economic loss from sea level rise | cc_slr_eco | ecological | climate change |
| sea surface temperature | cc_sst_eez | ecological | climate change |
| coral bleaching | cc_sst_nearshore | ecological | climate change |
| ocean warming | cc_uv | ecological | climate change |
| commercial fishery high bycatch | fp_com_hb | ecological | fishing pressure |
| commercial fishery low bycatch | fp_com_lb | ecological | fishing pressure |
| aquarium fishing | fp_fish_aquarium | ecological | fishing pressure |
| reef fishing catch | fp_reeffish_t | ecological | fishing pressure |
| forest/watershed health | hd_allien_veg | ecological | habitat destruction |
| habitat destruction of benthic structures | hd_benstr | ecological | habitat destruction |
| habitat destruction caused by coastal engineering | hd_coasteng | ecological | habitat destruction |
| habitat destruction from dredging | hd_dredging | ecological | habitat destruction |
| proxy for intertidal habitat destruction | hd_intertidal | ecological | habitat destruction |
| ship-based groundings | hd_shipbased_ground | ecological | habitat destruction |
| direct impacts from humans (trampling, recreation, etc) | hd_tourrec_direct_h | ecological | habitat destruction |
| visitors participating in snorkeling or scuba diving | t_ snorkel_scuba | ecological | habitat destruction |
| visitors participating in surfing | t_boarding | ecological | habitat destruction |
| visitors participating in kayaking | t_kayaking | ecological | habitat destruction |
| visitors participating in swimming | t_swimming | ecological | habitat destruction |
| visitors participating in thrill craft | t_thrill_craft | ecological | habitat destruction |
| visitors participating in whale watching | t_whale_watching | ecological | habitat destruction |
| land-based sediment export to nearshore water | po_lbsp_sed | ecological | pollution |

Table 21. Pressure layers and categories (continued).

| Data Layer | Short Name | Category | Subcategory |
|---|---|---|---|
| land-based source of pollution from agriculture and golf courses | po_lbspaggolfrunoff | ecological | pollution |
| landbased source of pathogens | po_lbspnosds_nflux | ecological | pollution |
| land-based source of pollution from urban runoff | po_lbspurbanrunoff | ecological | pollution |
| marine debris | po_marinedebris | ecological | pollution |
| ship-based pollution | po_shipbased_shipp | ecological | pollution |
| weakness of social progress | ss_spi | social | social |
| weakness of governance | ss_wgi | social | social |

Table 22. Pressure layers and weights applied to each goal and element.

| Goal | Element | t_snor-kel_scu-ba | t_whale_ watching | t_swim-ming | t_board-ing | t_kayak-ing | t_thrill_ craft | po_lbsp_ sed | po_lb-spurban-runoff | po_lb-spnosds_ nflux | po_lb-spag-gol-frunoff |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal Protection | Reef | | | | | | 1 | 2 | 2 | 2 | 2 |
| Coastal Protection | Wetland | | | | | | | | 2 | 2 | 2 |
| Coastal Protection | Beach | | | | | | | | 2 | 2 | 2 |
| Economies | Marine Construction | | | | | | | 2 | | | |
| Economies | Living Resources | | | | | | | 1 | | | |
| Economies | Ship and Boat Building | | | | | | | | 3 | | 3 |
| Economies | Tourism and Recreation | | | | | | | | | | |
| Economies | Marine Transportation | | | | | | | 1 | | | |
| Habitats | Reef | 1 | | 1 | 1 | | 1 | 2 | 2 | 2 | 2 |
| Habiatats | Wetland | | | | | | | | 2 | 2 | 2 |
| Habitats | Beach | | | 1 | | | | | | | |
| Habitats | Softbottom | | | | | | | | 2 | 2 | 2 |
| Livelihoods | Marine Construction | | | | | | | 1 | | | |
| Livelihoods | Living Resources | | | | | | | | 3 | 3 | 3 |
| Livelihoods | Ship and Boat Building | | | | | | | | | | |
| Livelihoods | Tourism and Recreation | | | | | | | 1 | 3 | 3 | 3 |
| Livelihoods | Marine Transportation | | | | | | | | | | |
| Mariculture | | | | | | | | | 2 | 2 | 2 |
| Nearshore Fisheries | | | | 1 | | | 2 | 1 | 1 | 1 | 1 |
| Offshore fisheries | | | | | | | | | | | |
| Sense of Place | | | | | | | | 2 | 2 | 3 | 2 |
| Species | | 1 | | 1 | | | 2 | 1 | | | |
| Sustainable Tourism | | | | | | | | 2 | 3 | 3 | 3 |

Table 22. Pressure layers and weights applied to each goal and element (continued).

| Goal | Element | po_ marined-ebris | po_ship-based_ shipp | sp_ aquacul_ terrest | sp_ ispp_a_m | hd_tour-rec_ direct_h | hd_ship-based_ ground | hd_ dredging | hd_coast-eng | hd_ben-str | hd_inter-tidal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal Protection | Reef | 1 | 1 | 1 | 1 | 2 | 3 | | 1 | 2 | |
| Coastal Protection | Wetland | | 1 | 1 | 1 | | | | 1 | 1 | 3 |
| Coastal Protection | Beach | | 1 | 1 | 1 | | | | 1 | 1 | 3 |
| Economies | Marine Construction | | 1 | | 1 | 2 | 2 | | | 1 | |
| Economies | Living Resources | | 1 | | 1 | 1 | 1 | | | 1 | 1 |
| Economies | Ship and Boat Building | | | | | | | | | | |
| Economies | Tourism and Recreation | 2 | | | | | | | | | |
| Economies | Marine Transportation | 2 | | | | | | | | | |
| Habitats | Reef | 3 | 1 | 1 | 1 | 2 | 3 | | | 2 | |
| Habiatats | Wetland | 2 | 1 | 1 | 1 | | | | | 1 | 3 |
| Habitats | Beach | 3 | 1 | | | | | | | 1 | |
| Habitats | Softbottom | | 1 | | 1 | | | 3 | | 1 | |
| Livelihoods | Marine Construction | | 1 | | 1 | 1 | 1 | | | 1 | 1 |
| Livelihoods | Living Resources | | | | | | | | | | |
| Livelihoods | Ship and Boat Building | 2 | | | | | | | | | |
| Livelihoods | Tourism and Recreation | | | | | | | | | | |
| Livelihoods | Marine Transportation | | 1 | | 1 | 1 | 1 | | | | |
| Mariculture | | | | | | | | | | | |
| Nearshore Fisheries | | 1 | 1 | 1 | 1 | 2 | 1 | | 1 | | 1 |
| Offshore fisheries | | 2 | 1 | | | | | | | | |
| Sense of Place | | 3 | | | | | | | | | |
| Species | | 2 | 1 | 1 | 1 | | | | | | 2 |
| Sustainable Tourism | | 3 | | | | | | | | | |

Table 22. Pressure layers and weights applied to each goal and element (continued).

| Goal | Element | fp_ reeffish_t | fp_fish_ aquarium | fp_com_ hb | fp_com_ lb | cc_sst_ eez | cc_sst_ near-shore | cc_acid | cc_uv | cc_sea-level | cc_slr_ eco |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal Protection | Reef | 3 | 1 | | | | 3 | 1 | 1 | | |
| Coastal Protection | Wetland | | | | | | | | | 1 | |
| Coastal Protection | Beach | | | | | | | | | 3 | |
| Economies | Marine Construction | | | | | | | 1 | | | 3 |
| Economies | Living Resources | 1 | | 3 | 1 | 1 | | | | | 3 |
| Economies | Ship and Boat Building | | | | | | | | | | 3 |
| Economies | Tourism and Recreation | | | 1 | | 1 | 2 | | | | 3 |
| Economies | Marine Transportation | | 1 | | | | | | | | 3 |
| Habitats | Reef | 3 | 1 | | | | 3 | 1 | 1 | | |
| Habiatats | Wetland | | | | | | | | | 1 | |
| Habitats | Beach | | | | | | | | | 3 | |
| Habitats | Softbottom | | | 3 | 1 | | | | | | |
| Livelihoods | Marine Construction | 1 | | 3 | 1 | | | | | | 3 |
| Livelihoods | Living Resources | | | | | | | | | | 3 |
| Livelihoods | Ship and Boat Building | | | 1 | | | | | | | 3 |
| Livelihoods | Tourism and Recreation | | 1 | | | | | | | | 3 |
| Livelihoods | Marine Transportation | 1 | | | | | | 1 | | | 3 |
| Mariculture | | | | | | | | | | 1 | |
| Nearshore Fisheries | | 1 | 1 | 2 | 1 | | | | | | |
| Offshore fisheries | | | | 3 | 1 | 3 | 1 | 3 | | | |
| Sense of Place | | | | | | | | | | | |
| Species | | 1 | 1 | 3 | 1 | 3 | 3 | 1 | 1 | | |
| Sustainable Tourism | | 1 | 1 | | | | | | | 2 | |

Table 22. Pressure layers and weights applied to each goal and element (continued).

| Goal | Element | ss_wgi | ss_spi | hd_al-lien_veg |
|---|---|---|---|---|
| Coastal Protection | Reef | 1 | 1 | 2 |
| Coastal Protection | Wetland | 1 | 1 | 2 |
| Coastal Protection | Beach | 1 | 1 | 2 |
| Economies | Marine Construction | 1 | 1 | |
| Economies | Living Resources | 1 | 1 | |
| Economies | Ship and Boat Building | 1 | 1 | |
| Economies | Tourism and Recreation | 1 | 1 | |
| Economies | Marine Transportation | 1 | 1 | |
| Habitats | Reef | 1 | 1 | 2 |
| Habiatats | Wetland | 1 | 1 | 2 |
| Habitats | Beach | 1 | 1 | 2 |
| Habitats | Softbottom | 1 | 1 | |
| Livelihoods | Marine Construction | 1 | 1 | |
| Livelihoods | Living Resources | 1 | 1 | 1 |
| Livelihoods | Ship and Boat Building | 1 | 1 | |
| Livelihoods | Tourism and Recreation | 1 | 1 | 1 |
| Livelihoods | Marine Transportation | 1 | 1 | |
| Mariculture | | 1 | 1 | |
| Nearshore Fisheries | | 1 | 1 | 1 |
| Offshore fisheries | | 1 | 1 | |
| Sense of Place | | | | 1 |
| Species | | 1 | 1 | 1 |
| Sustainable Tourism | | 1 | 1 | 3 |

Table 23. Resilience layers and categories.

| Data Layer | Short Name | Category | Category Type | Subcategory | Weight |
|---|---|---|---|---|---|
| habitat health | res_hab_health | ecological | ecosystem | ecological | 1 |
| management of nonindigenous species | sp_alien_species | ecological | regulatory | alien species | 1 |
| recycled wastewater | res_wastewa-ter_re-cycled | ecological | regulatory | ecological | 1 |
| access to shoreline | res_shoreline_access | ecological | regulatory | fishing pressure | 1 |
| artisanal fisheries management effectiveness and opportunity | fp_mora_artisanal | ecological | regulatory | fishing pressure | 1 |
| coastal MPAs fisheries resilience | fp_MPA_3nm | ecological | regulatory | fishing pressure | 1 |
| commercial fisheries reporting compliance | res_commercial_fis_compliance | ecological | regulatory | fishing pressure | 1 |
| commercial fishing management | fp_mora | ecological | regulatory | fishing pressure | 1 |
| community stewardship | communi-ty_steward-ship | ecological | regulatory | fishing pressure | |
| EEZ MPAs fisheries resilience | fp_MPA_eez | ecological | regulatory | fishing pressure | 1 |
| makai watch trainings | res_makai_watch | ecological | regulatory | fishing pressure | 1 |
| CITES signatories | g_cites | ecological | regulatory | goal | 0.5 |
| climate change adaptation plans | res_adoption_CCA | ecological | regulatory | goal | 1 |
| fishpond restoration support | res_fishpond_restora-tion | ecological | regulatory | goal | 1 |
| coastal MPAs habitat resilience | hd_MPA_3nm | ecological | regulatory | habitat destruction | 1 |
| EEZ MPAs habitat resilience | hd_MPA_eez | ecological | regulatory | habitat destruction | 1 |
| watershed partnerships | water-shed_partner-ships | ecological | regulatory | habitat destruction | 1 |
| watersheds protected | hd_watersheds | ecological | regulatory | habitat destruction | 1 |
| experience of visitors | tour-ism_experience | ecological | social | social | 1 |
| increase in shoreline access points | res_shoreline_ac-cess_points | ecological | social | social | 1 |
| community stewardship | communi-ty_steward-ship | social | social | social | 1 |
| Mo'omeheu - Value of History and Culture | sp_OHA_culture | social | social | social | 1 |
| sector evenness as a measure of economic diversity | li_sector_evenness | social | social | social | 1 |
| Social Progress Index | res_spi | social | social | social | 1 |
| State New Economy Index | li_economic_index | social | social | social | 1 |
| strength of governance | wgi_all | social | social | social | 1 |

Table 24. Resilience applied to each goal and element.

| Goal | Element | res_shore-line_ac-cess_ points | res_adop-tion_CCA | res_waste-water_re-cycled | res_ makai_ watch | res_com-mer-cial_ fis_compli-ance | res_fish-pond_res-toration | res_ shoreline_ access | hd_water-sheds | res_hab_ health | sp_OHA_ culture |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal Protection | Reef | | | | | | | | x | | x |
| Coastal Protection | Wetland | | x | x | | | | | x | | x |
| Coastal Protection | Beach | | x | x | | | | | x | | x |
| Economies | | | x | x | | | | | x | x | |
| Habitats | Reef | | | x | | | | | x | | x |
| Habiatats | Wetland | | | x | | | | | x | | x |
| Habitats | Beach | | | x | | | | | x | | x |
| Habitats | Softbottom | | | x | | | | | x | | x |
| Livelihoods | | | x | x | | | | | x | x | |
| Mariculture | | | | x | | | x | | | x | |
| Nearshore Fisheries | | x | | | x | | | x | x | x | |
| Offshore fisheries | | | | | | x | | | | | |
| Sense of Place | | | | x | | | | | x | x | x |
| Species | | x | | x | | | | | | x | |
| Sustainable Tourism | | | | x | | | | | | x | |

Table 24. Resilience applied to each goal and element (continued).

| Goal | Element | water-shed_ partner-ships | hd_ | hd_MPA_ eez | fp_ | fp_MPA_ eez | fp_mora | tour-ism_ experi-ence | g_cites | wgi_all | res_spi | li_eco-nomic_in-dex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal Protection | Reef | x | x | | | | | | | | | |
| Coastal Protection | Wetland | | x | | | | | | | | | |
| Coastal Protection | Beach | x | x | | | | | | | | | |
| Economies | | | | | x | | | | | | | x |
| Habitats | Reef | x | x | | | | | | | | | |
| Habiatats | Wetland | x | x | | | | | | | | | |
| Habitats | Beach | | x | | | | | | | | | |
| Habitats | Softbottom | | x | x | | x | x | | | | | |
| Livelihoods | | | | | | x | | x | | | | x |
| Mariculture | | | | | | | | | | | | |
| Nearshore Fisheries | | | x | | x | | x | | | | | |
| Offshore fisheries | | | | x | x | x | x | | | | | |
| Sense of Place | | | x | x | | x | x | | x | | | |
| Species | | x | x | | | | | | | | | |
| Sustainable Tourism | | x | x | x | x | x | | x | | | | |

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