**­­Hawai‘i Ocean Health Index**

**Summary**

The HawaiʻOcean Health Index is a scientifically robust index that measures ocean health for Hawaiʻi that is supported by local stakeholders that 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 Hawaiʻi.

**Background**

The Ocean Health Index is the first integrated assessment framework that scientifically combines key biological, physical, economic, and social elements of the ocean’s health. 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 Ocean Health Index were developed at a global scale, combining dozens of data sets to produce annual Index scores for coastal nations and territories. 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.

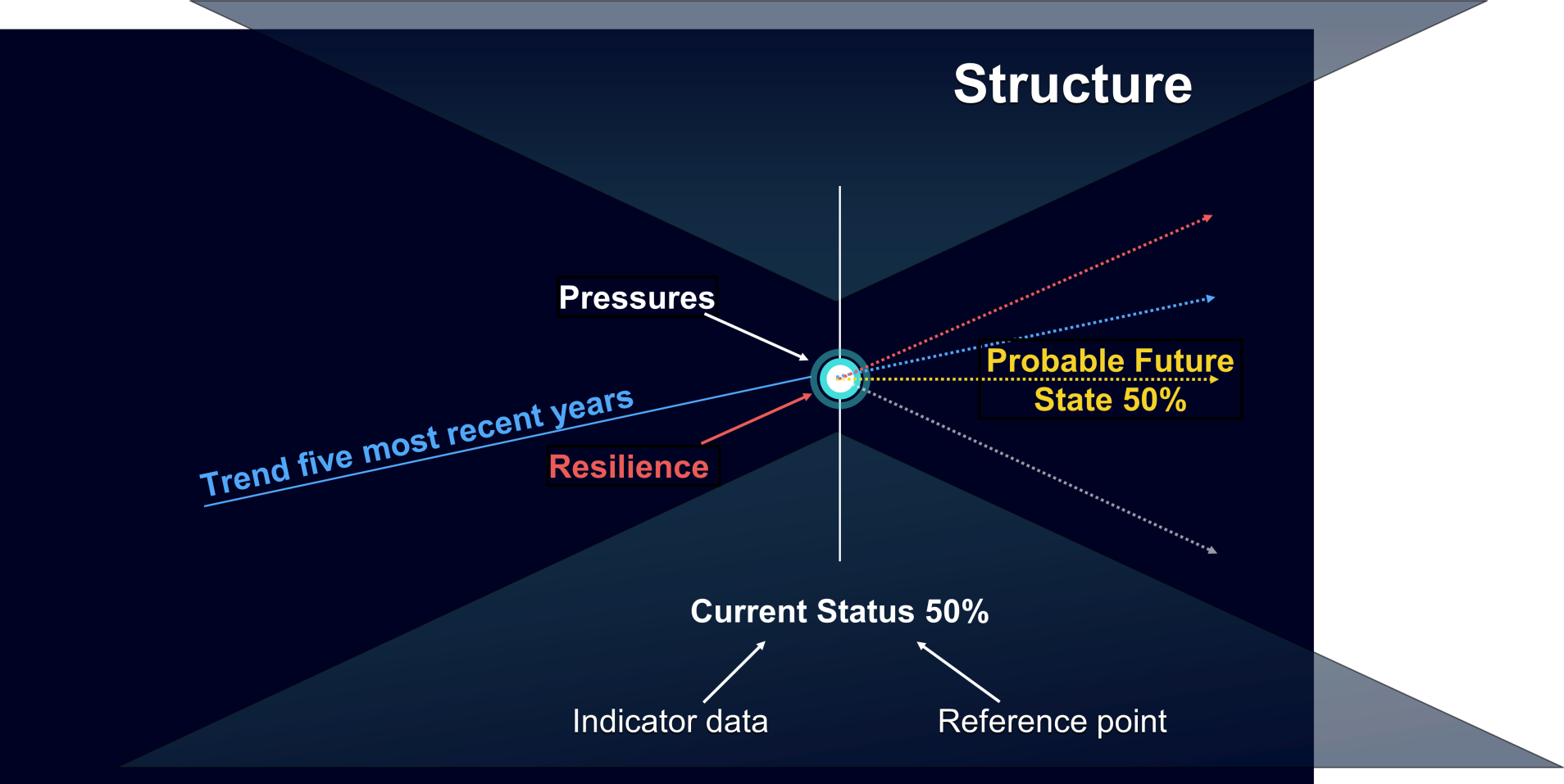
**Adapting the index for Hawaii**

Hawaiians have a long history of sustainable management and resource use. They recognized that their wellbeing and health relied on the status or availability of the resource. Today, the same is true; the health of our communities and our environment is intertwined. Healthy communities are more equipped to be stewards of their environment and a healthy environment supports community wellbeing. The core of mālama ʻāina and ocean health is through supporting community wellbeing and health. The strong sense of place or connection to the place that we have in Hawaii drives conservation and sustainability in Hawaiʻi and is a model for the rest of the world. Hawaii’s unique social and cultural practices and values are the foundation for the development of every goal and are also tracked in their own goal, Sense of Place (The Sense of Place Goal accounts for the importance of the relationship between people and ʻāina and relationships among people with regards to the past, present and future).

**Methods**

**OHI Framework**

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



Caption: The framework to assess ocean health index goal scores includes the current status (50% of the goal score) and probable future state (50% of the goal score). The current status is calculated using available indicators in relation to a stakeholder set reference point. The probable future status 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 global Ocean Health Index 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. These goals for the OHI were adapted from the global framework and transformed into seven goals for the Hawaiʻi OHI: Food Provision, Coastal Protection, Biodiversity, Economies & Livelihoods, Artisanal Fishing Opportunities, Sustainable Tourism, and Sense of Place.

**Calculating the Index**

Basic equations for calculating the index here – references to appendix materials and Halpern 2012.

**Study Area**

The Hawaiʻi OHI was a statewide assessment for the Main Hawaiian Islands. The assessment was done at the county scale (Hawaiʻi, Maui Nui, Oahu, and Kauai) and averaged to produce the overall Hawaiʻi Ocean Health Index score. The OHI focus is on the entire EEZ, however, some goals are assessed on the nearshore (3 nm scale).

Table #. Spatial extent of goal models.

|  |  |  |
| --- | --- | --- |
| **Goal** | **Sub-Goal** | **Primary Scale of Goal** |
| Food Provision | Fisheries | EEZ |
| Mariculture | Nearshore |
| Artisanal Fishing Opportunities |  | Nearshore |
| Coastal Protection |  | Nearshore |
| Tourism & Livelihoods |  | EEZ |
| Sustainable Tourism |  | Nearshore |
| Sense of Place |  | Nearshore |
| Biodiversity | Species | EEZ |
| Habitats | EEZ |

**Process for Developing the Hawaii OHI**

The OHI+ framework was developed for Hawaii through the following process.

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**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.

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

**Plan** the assessment to achieve local objectives and involve stakeholders

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

The Ocean Health Index was adapted to Hawaii through the support of local experts, stakeholder surveys, expert working groups, workshops, and meetings with management agencies. A coalition for sustainable ocean management was built through bringing together management agencies, stakeholders, and organizations to support sustainable ocean management through a clear vision of ocean health and a united common goal of assessing and tracking ocean health in Hawaiʻi. The conceptual framework of the Hawaii OHI assessment was adapted from the global OHI framework to meet Hawaii’s unique ecological, social, economic, and cultural aspects.

**Synergies with Existing Regional and Statewide Ocean Sustainability Initiatives**

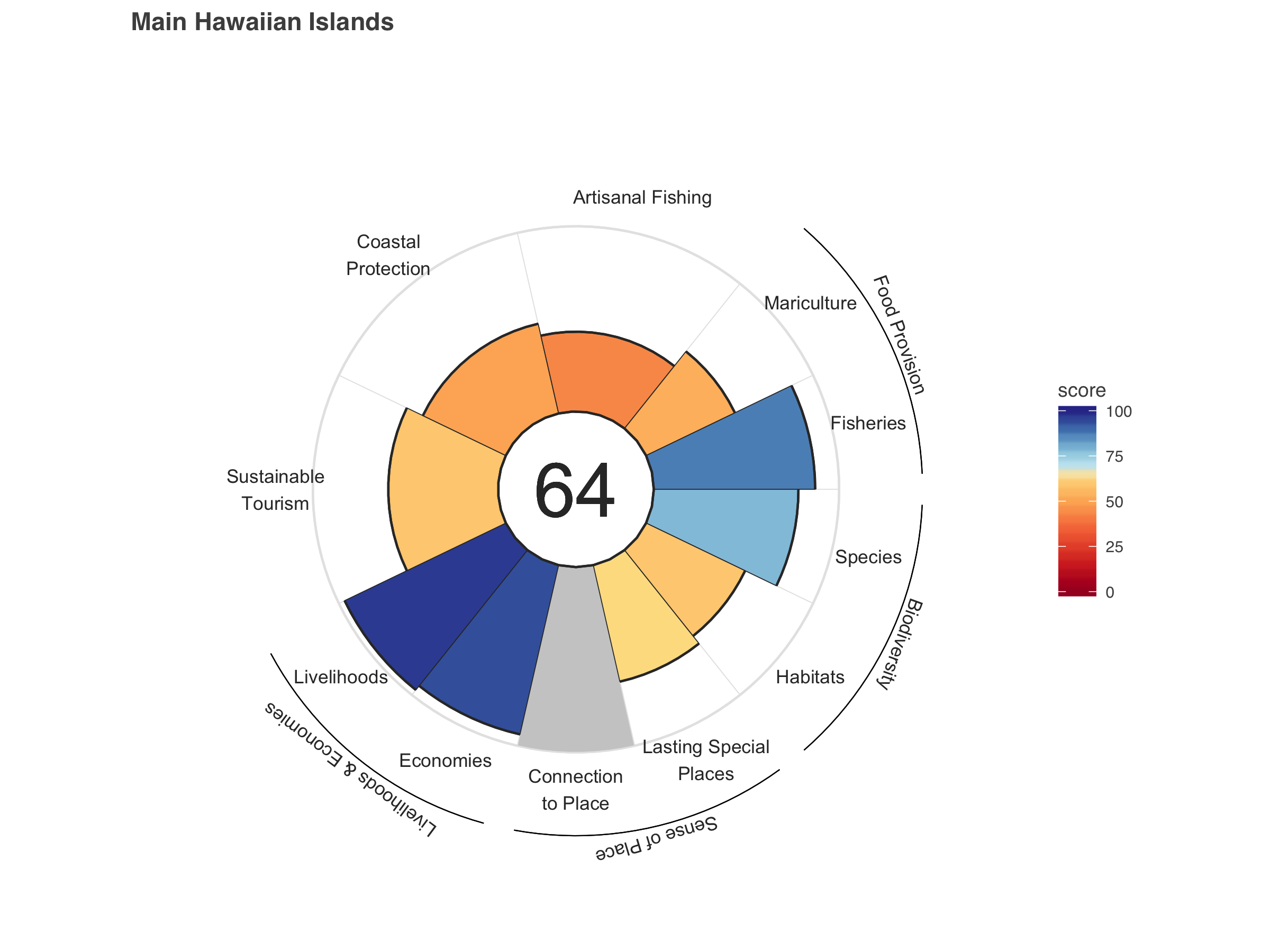
The Hawai‘i Ocean Health Index support the *Aloha+ Challenge* targets through measuring ocean health under the Natural Resources target on the Governor’s Dashboard. The *Aloha+ Challenge* is a joint leadership commitment to sustainability for the State of Hawai‘i that was launched by Hawai‘i’s Governor, its four mayors, and the Office of Hawaiian Affairs in July 2014. The *Aloha+ Challenge* sets six statewide sustainability targets to be achieved by 2030 – in clean energy transformation, local food production, natural resource management, solid waste reduction (discarded resource recovery), smart growth, climate resilience, green job creation, and education. The purpose of these targets is to provide a shared framework to set priorities, take action, and track progress toward a more sustainable and resilient Hawai‘i.

Table 1. Locally defined goals for the Hawaiʻi OHI+ assessment.

|  |  |  |
| --- | --- | --- |
| Goal | Subgoal | Definition |
| Food Provision (FP) | Fisheries (FIS) | Sustainably harvested or cultured seafood. Fisheries measures the amount of wild-caught seafood from pelagic, bottomfish, coastal pelagic and nearshore fisheries that can be sustainably harvested. Mariculture assesses the sustainable production of seafood from contemporary mariculture and customary Hawaiian fishponds (loko i‘a). |
| Mariculture (MAR) |
| Artisanal Fishing Opportunities (AO) |  | The opportunity for fishers to supply seafood for themselves, families, and community. It is estimated access to the resource and the availability of the resource (fish biomass). |
|
| Sense of Place (SP) | Lasting Special Places (LSP) | The relationship between people and ‘āina (land/environment) and relationships among people with regards to the past, present and future. Lasting special places subgoal tracks the protection of marine and coastal areas. Connection to place subgoal measures the connection that people have to coastal and marine environments measured through activities that take occur in each place. |
|
| Connection to Place (CON) |
| Sustainable Tourism (ST) |  | Balanced economic growth through tourism with management and preservation of natural resources and Hawaiian culture. |
|  |
| Biodiversity (BD) | Habitats (HAB) | The value of coastal and ocean species and habitats. The habitat subgoal measures the extent and condition of reefs, wetlands, soft-bottom habitats, and beaches. The species subgoal 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) |  | Extent and condition of habitats (beaches, coral reefs, wetlands) that provide coastal protection from inundation and erosion. |
| Livelihoods & Economies (LE) | Livelihoods (LIV) | Coastal and ocean-dependent jobs and productive coastal economies from the revenue from marine related industries including tourism, fishing, shipbuilding, and transportation. Livelihoods tracks the number of jobs and the quality of wages (wage/livable wage) of marine sectors. Economies tracks the revenue generated from productive coastal economies. |
|
| Economies (ECO) |

**Results**

**Hawaiʻi Ocean Health Index**

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Results table and results map for regions

Table #. Goal scores for the Main Hawaiian Islands and regional scores.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Region |  | FP | | AO | SP | | ST | BD | | CP | LE | |
| FIS | MAR |  | LSP | CON |  | HAB | SPP |  | LIV | ECO |
| Main Hawaiian Islands | | 87 | 53 | 45 | 64 |  | 59 | 59 | 78 | 50 | 92 | 94 |
| Hawaiʻi |  | 89 | 73 | 49 | 92 |  | 59 | 51 | 80 | 46 | 94 | 100 |
| Maui Nui |  | 83 | 41 | 42 | 81 |  | 72 | 68 | 78 | 54 | 97 | 74 |
| Oahu |  | 85 | 34 | 41 | 46 |  | 51 | 46 | 72 | 42 | 88 | 100 |
| Kauai & Niʻihau |  | 91 | 64 | 46 | 36 |  | 54 | 71 | 81 | 57 | 84 | 100 |

**Food Provision**

Over half (55%) of available seafood in Hawaii is locally sourced, percentages of fisheries and mariculture. Over 30 million pounds of seafood are caught in Hawaiʻi annually

**Wild Caught Fisheries**

Nearly 34 million pounds of seafood are caught in Hawaiʻi annually (Table #). The majority of the catch is from the pelagic fishery (tunas, marlin, swordfish, etc). Wild caught fisheries received a score of 87 reflecting that the majority of the catch comes from sustainable fisheries. However, it is important to note that the fisheries sustainability scores are declining over time for most species assessed, reducing the future sustainability of many of the species assessed which have the potential to have larger ecosystem impacts.

Table # Total catch (2016) for each fishery (reef, bottom, coastal pelagic, and pelagic) and mean sustainability score.

|  |  |  |
| --- | --- | --- |
| Fishery | Mean Annual Catch (lbs) | Mean Sustainability Score |
| Reef | 2,694,641 | 0.81 |
| Bottomfish | 428,181 | 0.88 |
| Coastal Pelagic | 583,030 | NA |
| Pelagic | 30,230,053 | 0.80 |

|  |  |  |  |
| --- | --- | --- | --- |
| Region | Fishery | Mean Annual Catch (lbs) | Mean Sustainability Score |
| Hawaiʻi | reef | 712,881 | 0.79 |
| Maui Nui | reef | 588,158 | 0.80 |
| Oahu | reef | 1,215,432 | 0.79 |
| Kauai & Niʻhau | reef | 178,170 | 0.86 |
| Hawaiʻi | bottomfish | 86,448 | 0.88 |
| Maui Nui | bottomfish | 235,011 | 0.88 |
| Oahu | bottomfish | 51,677 | 0.88 |
| Kauai & Niʻhau | bottomfish | 55,045 | 0.88 |
| Hawaiʻi | coastal pelagic | 159,923 | NA |
| Maui Nui | coastal pelagic | 81,727 | NA |
| Oahu | coastal pelagic | 285,885 | NA |
| Kauai & Niʻhau | coastal pelagic | 55,495 | NA |
| EEZ | pelagic | 30,230,053 | 0.80 |

**Mariculture**

**Artisanal Fishing Opportunities**

Table # Artisanal fishing opportunities indicators (shoreline access, resource biomass) and combined status and trend for each region.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region | Access | Resource | Status | Trend |
| Hawaiʻi | 0.64 | 0.66 | 0.65 | 0.01 |
| Maui Nui | 0.56 | 0.66 | 0.61 | -0.01 |
| Oahu | 0.68 | 0.54 | 0.61 | 0.04 |
| Kauai & Niʻihau | 0.56 | 0.72 | 0.64 | 0.02 |

**Sustainable Tourism**

Hawaiʻi’s economy is heavily reliant on the tourism industry. Scores ranged from 51 to 71 by region (Table #). The low scores reflect the decrease in visitor generated revenue in 2013 -2015 and the need to balance the economic gains with the preservation of Hawaiʻi’s unique cultural and natural environment. Stakeholders have identified several areas to improve to increase preservation of social and cultural values and the natural environment. These include increased tourism education programs and increased proportion of the tax revenues generated from the tourism industry allocated to community and environmental preservation.

Table #. Sustainable Tourism scores by region.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region | Goal | Status | Trend | Score |
| Hawaii | ST | 62 | -0.29 | 59 |
| Maui Nui | ST | 75 | -0.25 | 71 |
| Oahu | ST | 56 | -0.4 | 51 |
| Kauai | ST | 59 | -0.4 | 53 |

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Region | Year | Economic | Sentiment | Environment | Status |
| Hawaiʻi | 2011 | 100 | 67 | 42 | 70 |
| 2012 | 100 | 61 | 42 | 68 |
| 2013 | 63 | 64 | 42 | 56 |
| 2014 | 88 | 64 | 42 | 65 |
| 2015 | 50 | 61 | 42 | 51 |
| Maui Nui | 2011 | 100 | 67 | 72 | 80 |
| 2012 | 100 | 61 | 72 | 78 |
| 2013 | 100 | 64 | 72 | 79 |
| 2014 | 92 | 64 | 72 | 76 |
| 2015 | 50 | 61 | 72 | 61 |
| Oahu | 2011 | 100 | 67 | 35 | 67 |
| 2012 | 100 | 61 | 35 | 65 |
| 2013 | 50 | 64 | 35 | 50 |
| 2014 | 50 | 64 | 35 | 49 |
| 2015 | 50 | 61 | 35 | 49 |
| Kauai & Niʻihau | 2011 | 100 | 67 | 34 | 67 |
| 2012 | 100 | 61 | 34 | 65 |
| 2013 | 100 | 64 | 34 | 66 |
| 2014 | 50 | 64 | 34 | 49 |
| 2015 | 50 | 61 | 34 | 48 |

**Livelihoods and Economy**

Ocean revenues contribute over 6 billion to Hawaii’s economy each year and directly provide 16% of jobs (103,427 in 2013).

Table # Ocean contribution to Hawaii’s livelihoods and economy.

|  |  |  |  |
| --- | --- | --- | --- |
| Region | Total Ocean Sector Jobs | Percent of Jobs per Region | Revenue (mil) |
| Hawaii | 13,576 | 16% | 993.2 |
| Maui Nui | 25,423 | 32% | 2,165.5 |
| Oahu | 59,164 | 13% | 2,700.1 |
| Kauai | 5,264 | 16% | 217.9 |

**Livelihoods**

The tourism and recreation sector represents 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 2014) and 36% below the self-sufficiency standard (DBEDT 2015).

**Economies**

**Goals**

**Food Provision**

Measures the sustainably harvested and produced seafood from fisheries catch and aquaculture (local production of seafood including shrimp ponds and fishponds).

**Wild Caught Fisheries**

This sub-goal describes the amount harvested and sustainability of Hawaii’s fisheries. The model generally compares landings with Maximum Sustainable Yield. A score of 100 means that the region is harvesting seafood in a sustainable manner.

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

The goal status score for each region in each year was calculated as average scores from each fishery calculated as the geometric 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, opelu, etc.; nearshore: surgeonfish, parrotfish, etc.). The model assesses the amount of wild-caught seafood that can be sustainably harvested from within the Hawaiʻi EEZ, with sustainability (stock status scores) based on formal stock assessments. Longline data for pelagic species landed in Hawaiʻi but caught outside of the OHI assessment region (Main Hawai’i Island EEZ) are not included in the assessment. Each stock is assessed separately based on stock status scores (Biomass at maximum sustainable yield: B/Bmsy; Spawning biomass at maximum sustainable yield: SB/SBmsy; and Spawning Potential Ratio: SPR). We applied a 0.05 upper and lower buffer on the stock status score allowing for error in the stock status.

Stock status reference points typically used in formal stock assessments vary by the fishery type in Hawaiʻi. Pelagic fish sustainability reference point is SB/SBmsy set to 1.0. Bottomfish species sustainability reference point is B/BMSY set to 1.0. Reef fish sustainability reference point is the spawning potential ratio (SPR) set to 0.30. The most recent stock assessments for pelagic fish species were 2012-2013 for most species. 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. The stock indicator for pelagic species was SB/SBmsy. Bottom fish stock assessments were for the aggregated species complex for the Hawaiʻi deep 7 and we used B/Bmsy as the stock indicator (Brodziak et al. 2014). Reef fish stock assessment used the spawning potential ratio (SPR) as the stock indicator and only one assessment is available (Nadon 2017) so the stock status was held constant over the 5 assessment years. We used median scores for each group (pelagic, bottom, coastal pelagic, and reef) to gap fill for species that lack formal stock assessments. To include these important harvest species, we made the assumption that the unassessed species within each fishery (pelagic, bottomfish, nearshore/reef, coastal pelagic) are faring similarly to the assessed fish stocks. There were no current formal stock assessments for coastal pelagic species 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 # Mean annual catch (lbs) from 2012 to 2016 and sustainability score for reef and nearshore species.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Mean Annual Catch (lbs) | Score | Species | Mean Annual Catch (lbs) | Score | Species | Mean Annual Catch (lbs) | Score |
| Aawa | 25,894 | 0.81 | Kole | 21,143 | 0.53 | Opelu kala | 26,052 | 0.43 |
| Ahaaha | 2,562 | 0.81 | Kumu | 25,769 | 0.50 | Pakii | 46 | 0.81 |
| Aholehole | 14,351 | 0.81 | Kupipi | 657 | 0.81 | Pualu | 33,252 | 0.40 |
| Alaihe | 3,002 | 1.00 | Kupoupou | 37 | 0.81 | Puhi black | 2,229 | 0.81 |
| Alaihe mama | 389 | 1.00 | Laenihi | 24,306 | 0.81 | Puhi eel-misc. | 1,645 | 0.81 |
| Amaama | 17,175 | 0.81 | Maiko | 6,591 | 0.53 | Puhi white | 872 | 0.81 |
| Api | 532 | 0.54 | Malu | 673 | 0.87 | Randall's snapper | 646 | 0.90 |
| Awa | 4,590 | 0.81 | Manini | 61,199 | 0.53 | Roi | 11,528 | 0.84 |
| Awaawa | 2,732 | 0.81 | Maomao | 7,215 | 0.81 | Summer mullet | 1,574 | 0.82 |
| Aweoweo | 41,588 | 0.81 | Menpachi | 381,403 | 1.00 | Tilapia | 5,917 | 0.82 |
| Aweoweo (deepsea) | 1,537 | 0.81 | Moana | 29,994 | 0.87 | Toau | 20,811 | 1.00 |
| Black kole | 1,103 | 0.53 | Moana kale | 14,826 | 0.80 | Uhu parrot-misc. | 1,077,847 | 0.97 |
| Ea (wrasse) | 1,043 | 0.81 | Moi | 1,239 | 0.81 | Umaumalei | 21,173 | 0.83 |
| Golden kali | 2,033 | 0.81 | Mu | 19,864 | 1.00 | Uouoa | 3,229 | 0.81 |
| Hauliuli | 116 | 0.81 | Munu | 2,870 | 1.00 | Wahanui | 329 | 0.89 |
| Hinalea | 85 | 0.81 | Naenae | 21,934 | 0.53 | Weke | 2,185 | 0.87 |
| Hogo | 11,572 | 0.81 | Nenue | 97,275 | 0.81 | Weke a'a | 20,509 | 1.00 |
| Humuhumu | 2,659 | 0.81 | Nohu | 8,368 | 0.81 | Weke nono | 38,174 | 1.00 |
| Iheihe | 378 | 0.82 | Nunu | 872 | 0.81 | Weke pueo | 2,083 | 0.87 |
| Kaku | 13,695 | 0.81 | Oio | 33,402 | 0.81 | Weke ula | 142,784 | 1.00 |
| Kala | 239,064 | 0.29 | Olililepa | 3,893 | 0.81 |  |  |  |
| Kawelea | 18,403 | 0.81 | Oopuhue | 3,478 | 0.82 |  |  |  |

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

|  |  |  |
| --- | --- | --- |
| Species | Mean Annual Catch (lbs) | Score |
| Alfonsin | 35 | 0.88 |
| Butaguchi ulua | 306 | 0.88 |
| Gunkan ulua | 366 | 0.88 |
| Kahala | 15,621 | 0.88 |
| White ulua | 13,177 | 0.88 |
| Ehu | 30,173 | 0.84 |
| Gindai | 3,001 | 0.84 |
| Kalekale | 14,257 | 0.84 |
| Lehi | 10,332 | 0.84 |
| Onaga | 61,830 | 0.84 |
| Opakapaka | 130,982 | 0.84 |
| Taape | 31,373 | 1.00 |
| Uku | 110,802 | 0.98 |
| Hapuupuu | 9,194 | 0.84 |

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

|  |  |  |
| --- | --- | --- |
| Species | Mean Annual Catch (lbs) | Score |
| Akule | 313,584 | NA |
| Barred jack | 50 | NA |
| Dobe ulua | 3,348 | NA |
| Hahalalu | 17,899 | NA |
| Kagami ulua | 221 | NA |
| Kamanu | 4,355 | NA |
| Lae | 254 | NA |
| Omaka | 28 | NA |
| Omilu | 6,846 | NA |
| Opelu | 223,704 | NA |
| Opelu 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 # Mean annual catch (lbs) from 2012 to 2016 and sustainability score for pelagic species.

|  |  |  |
| --- | --- | --- |
| Species | Mean Annual Catch (lbs) | Score |
| Thresher | 20,118 | 0.80 |
| Monchong | 1,168,014 | 0.80 |
| Blue | 17,780 | 0.93 |
| Oceanic | 462 | 0.93 |
| Mahimahi | 1,661,441 | 0.80 |
| Blue marlin | 1,489,631 | 1.00 |
| Misc Istiophoridae Species | 2,234 | 0.68 |
| Sailfish | 46,248 | 0.68 |
| Striped marlin | 1,005,382 | 0.37 |
| Mako | 119,501 | 0.80 |
| Bigeye tuna | 16,523,199 | 0.82 |
| Bluefin | 1,077 | 0.39 |
| Kawakawa | 18,179 | 0.80 |
| Ono | 1,075,297 | 0.80 |
| Tombo | 925,796 | 1.00 |
| Yellowfin tuna | 4,070,707 | 1.00 |
| Swordfish | 2,084,987 | 1.00 |

*Data Layers & References*

* Commercial (pelagic, bottomfish, coastal pelagic, reef) catch data (2012-2016, DLNR Division of Aquatic Resources)
* Non-commercial catch data (used as a multiplier for commercial catch data): McCoy et al in review
* Reef fish stock assessment: Nadon, M. O. 2017. Stock assessment of the coral reef fishes of Hawaii, 2016. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-60, 212 p. doi:10.7289/V5/TM-PIFSC-60.
* Bottomfish stock assessment: Brodziak, J., A Yau, J. O’Malley, A. Andrews, R. Humphreys, E. DeMartini, M. Pan, M. Parke, and E. Fletcher. 2014. Stock assessment update for the main Hawaiian Islands Deep 7 bottomfish complex through 2013 with projected annual catch limits through 2016. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-42, 61 p. doi:10.7289/V5T151M8
* Pelagic fish stock assessments can be found at: Western & Central Pacific Fisheries Commission (<https://www.wcpfc.int/)> and the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (http://isc.fra.go.jp) .

*Data Gaps*

* Bottom fish taxonomic resolution for the stock assessment was not assessed to species.
* Public perception of fisheries status.
* Catch from recreational fisheries is estimated through a formal scientific study that used social surveys to derive catch estimates. The number of recreational fishers and the recreation catch remains unknown.
* Estimates of non-reported commercial catch.
* Dealer reporting.
* Lacking stock assessments for many of the harvested fish species and all of the coastal pelagic species.
* Invertebrates are not included such as opihi (limpets), sea cucumbers, heʻe (octopus), lobster, and others. They were excluded from the assessment because there is not an estimate of recreational catch, which is thought to be a large proportion of the catch, and stock assessments are lacking for most of these species.

**Mariculture**

This subgoal of Food Provision measures the sustainable production potential of seafood from fishponds, known locally as loko iʻa, 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.

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*), kahala (*Seriola dumerili*), Pacific White Shrimp (*Penaeus vannamei*), and limu (Gracilaria sp.). Moi (Pacific Threadfin) is not on the State of Hawaii Department of Agriculture list but it is produced locally for out planting in fishponds. 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).

The production (lbs of seafood) is reported at the state level to prevent disclosure of sensitive information. To get county level estimates of production the lbs of finfish and shellfish produced at the state level were multiplied by the estimated number of finfish and shellfish operators by county. The number of operators are reported to USDA via census every 5 years (2002, 2007, 2012) ([https://www.nass.usda.gov/Statistics\_by\_State/Hawaii/](https://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Annual_Statistical_Bulletin/index.php) ). To fill in annual data gaps linear regression models were used.

*Data Layers & References*

* Mariculture species list: HawaiʻI Department of Agriculture (<http://hdoa.hawaii.gov/ai/aquaculture-and-livestock-support-services-branch/aquaculture-in-hawaii/)>.
* Mariculture yield: US DOA. 2015. Hawaiʻi Aquaculture Annual Release.
* Number of mariculture operators: USDA (<https://quickstats.nass.usda.gov/)>
* Fishponds: TNC updated fishpond layer 2017

*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.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 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 Sikamea* | 1 | 1 | 1 | 0.5 | 0.88 |
| Tilapia | *Oreochromis* sp | 0 | 0 | 0 | 0 | 0.00 |

**Artisanal Fishing Opportunities**

This goal measures the benefits that the ocean provides for subsistence or artisanal fisheries and is measured by the access to the resource and the status of the resource.

Access was defined as ease of shoreline accessibility (and boat-based access (). Resource condition was defined at the current nearshore fish biomass (compared to pristine nearshore fish biomass ().

Shoreline access was calculated as the present of the coastline that is accessible to fishers. No-take Marine Protected Areas, military areas, and very steep coastlines were considered inaccessible and the remaining coastline accessibility was weighted by the ease of access based on road availability (within 500 meters) and slope (Table 3). Boat-based access was calculated as the distance to harbors or boat ramps.

Nearshore fish biomass and pristine biomass comes from the NOAA Coral Reef Ecosystem Program where the reference fish biomass () is the modeled pristine reef fish biomass in the absence of humans (Williams et al 2015). Trend was calculated as the combined change in the resource and access over the past 5 years 2010-2015.

Table #. Shoreline accessibility weights and descriptions.

|  |  |
| --- | --- |
| Weight | Description |
| 1.0 | High accessibility coastline |
| 0.75 | Moderate accessibility coastline with flat to moderate slopes near unpaved roads |
| 0.5 | Low accessibility coastlines with flat to moderate slopes near private roads or with no nearby road access |
| 0 | No access coastlines with cliffs or steep shorelines, no-take marine protected areas, and military areas |

*Data Layers & References*

* Access: modified from Lecky 2017 Cumulative Impact Mapping
* Fish Biomass: Williams, I. D., Baum, J. K., Heenan, A., Hanson, K. M., Nadon, M. O., & Brainard, R. E. (2015). Human, oceanographic and habitat drivers of central and western Pacific coral reef fish assemblages. *PLoS One*, *10*(4), e0120516.
* Trend: NOAA CREP 2017 report (citation here)

*Data Gaps*

* Biomass of harvest fish from open access areas (with biomass from MPAs not included in the assessment).
* Number of fishers
* Fish flow
* Catch and effort data

**Sustainable Tourism**

This goal strives to measure the balance between economic growth through tourism with management and preservation of natural resources and Hawaiian culture. This is measured through tracking ocean and coastal management areas to preserve the environment and provide visitor ecotourism opportunities and the sentiment of residents of tourism. Sustainable tourism was scored based on the benefit of visitors to economic growth (*economic (r))* while taking into account thepreservation of social and cultural values of residents *(sentiment (s))* and protection of the natural environment (*environment (p)).*

*ec=*current annual growth in visitor generated revenue (GDP)

*er=* reference annual growth rate in visitor generated revenue of +2.5%

*r ≥*2.5% = 1

*r>*1.5% and *r*>2.5% =*r*

*r≤*1.5% and *r ≥ =* -0.3% *=*0.5

*sc=* current sentiment

*sr=*reference sentiment target of 80%

*pc =*current percent of nearshore waters and priority watersheds protected

*p30 =*30% percent of nearshore waters and priority watersheds protected

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

*Economic* was scored based on county estimated visitor generated GDP. Visitor contribution to the economy was measured in USD inflation adjusted (real) GDP. The reference level for visitor contribution to economic growth was set at $13,280 mil by 2020 or 2.5% annual growth rate (HTA 2016 Annual Report). Visitor generated GDP was estimated to county level by weighting GDP by the average daily number of visitors to each county (visitors defined as overnight stays (DBEDT 2016)).

*Sentiment* scores the preservation of social and cultural values estimated though HTA visitor sentiment surveys. 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 Hawaiʻi. 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 Hawaii. Questions were averaged and scored to a reference value of 80 as set by the Hawaiʻi Tourism Authority as their target acceptance rate (HTA 2016 Annual Report).

*Environment* scores 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 the Aloha+ dashboard on marine managed areas (DLNR Division of Aquatic Resources) and DLNR Division of Forestry and Wildlife. 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 (https://governor.hawaii.gov/sustainable-hawaii-initiative/).

*Data Layers & References*

* Economic: Hawaiʻi Tourism Authority. 2016 Annual Report to the Hawaiʻi State Legislature. Available: <http://www.hawaiitourismauthority.org/default/assets/File/HTA%20Annual%20Report%202016%20FINAL.pdf>.
* Sentiment: Hawaiʻi Tourism Authority Visitor Satisfaction and Activity Reports 2011-2015. Available: <http://www.hawaiitourismauthority.org/research/reports/visitor-satisfaction/>.
* Environment: Marine Managed Areas (DAR). Hawaiʻi State Office of Planning. Hawaiʻi Statewide GIS Program Geospatial Data Portal. Available: <http://geoportal.hawaii.gov/datasets/marine-managed-areas-dar?geometry=-165.4%2C19.079%2C-149.745%2C22.671>.
* Average number of overnight visitors per day: State of Hawaiʻi Department of Business, Economic Development and Tourism. Data Books from 2011-2015. Recreation and Travel. Available: <http://dbedt.hawaii.gov/economic/databook/>.

*Data Gaps*

* Data on park signage and education programs not comprehensive or available state wide.
* An agreed upon plan for sustainable tourism, economic growth, and ecotourism has not been established.
* It is unknown how much of the Tourism Accommodation Tax (TAT) goes back to environmental protection and restoration.

**Livelihoods & Economies**

This goal measures the contribution of oceans to our livelihoods and economy. The goal includes the two subgoals: Livelihoods (and Economy ().

Data on ocean livelihoods and economies comes from the NOAA ENOW for employment (jobs), wages, and revenue by ocean sector. Sectors include: Marine Construction, Living Resources, Ship and Boat Building, Tourism and Recreation, and Marine Transportation. 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.

Table # Ocean livelihood and economy sectors.

|  |  |
| --- | --- |
| 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 |

**Livelihoods**

This sub-goal, Livelihoods, describes 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. Livelihoods was measured as the mean of ocean jobs and wages measured as the current number of jobs (*jc*) per marine and ocean sector (*k*) in relation to a reference year (*jr;* 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 ENOW (<https://coast.noaa.gov/digitalcoast/tools/enow.html>) and was adjusted by state unemployment rate (DBEDT) (Halpern et al. 2012).

*Data Layers & References*

* Resident population: State of Hawaiʻi Department of Business, Economic Development and Tourism 2015 Data Book. Section 1. Population. Available: <http://dbedt.hawaii.gov/economic/databook/db2015/>.
* Workforce (total number of jobs by county): State of Hawaiʻi Department of Business, Economic Development and Tourism 2015 Data Book. Section 12. Labor Force, Employment, and Earnings. Available: <http://dbedt.hawaii.gov/economic/databook/db2015/>.
* Unemployment rate: State of Hawaiʻi Department of Business, Economic Development and Tourism 2015 Data Book. Section 12. Labor Force, Employment, and Earnings. Available: <http://dbedt.hawaii.gov/economic/databook/db2015/>.
* Jobs: Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Office for Coastal Management (OCM). 2017. Time-Series Data on the Ocean and Great Lakes Economy for Counties, States, and the Nation between 2005 and 2014 (Sector Level), Charleston, SC, Available: <https://coast.noaa.gov/digitalcoast/tools/enow.html>.
* DBEDT Research & Economic Analysis Division (2015) Self-sufficiency income standard. Hawaii Economic Issues. p1-29. Available: (http://files.hawaii.gov/dbedt/economic/reports/self-sufficiency/self-sufficiency\_2014.pdf)

*Data Gaps*

* Some sectors are not well represented in Livelihoods and Economies, such as pro-surfers and marine and ocean scientists.
* The reference for wages is the bare minimum salary to live on without needing governmental aid. A livable wage is another possible reference point but is difficult to measure. Another alternative reference point could be annual per capita average consumption expenditures by county.

**Economies**

Economies captures the economic value associated with marine industries using revenue from marine sectors. It 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 ENOW (<https://coast.noaa.gov/digitalcoast/tools/enow.html>).

Table #. Industry multipliers for indirect jobs and revenue (DBEDT 2007, http://files.hawaii.gov/dbedt/economic/reports/IO/2007\_state\_io\_study.pdf). 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 & References*

* Revenue: Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Office for Coastal Management (OCM). 2017. Time-Series Data on the Ocean and Great Lakes Economy for Counties, States, and the Nation between 2005 and 2014 (Sector Level), Charleston, SC, Available: <https://coast.noaa.gov/digitalcoast/tools/enow.html>.
* Research and Economic Analysis Division, Department of Business, Economic Development and Tourism. State of Hawaiʻi. 201. The Hawaiʻi State Input-Output Study: 2007 Benchmark Report.

*Data Gaps*

* Some sectors are not well represented in Livelihoods and Economies, such as pro-surfers and marine and ocean scientists.
* Sector evenness is not taken into account in the model.

**Sense of Place**

Cultural values are expressed in the development of this goal and several of the other goals and we recognize local and culture values as important to all aspects of ocean health. This goal stresses the importance of past, present, and future for the connection of people to places (āina) and relationships or networks of people with each other. Together these define community. This goal is composed of two subgoals: Lasting Special Places and Connection to Place. Lasting special places tracks the protection of marine and coastal areas. Connection to place is the connection that people have to coastal and marine environments.

**Lasting Special Places**

Lasting special places tracks the protection of marine and terrestrial coastal areas with the emphasis on protecting cultural and sacred sites. Clipped NOAA MPA inventory layer to 3nm offshore. MPAs classified by no take, no access, zoned with no take, and zoned with multiple use and zoned with uniform use. All MPAs with no take, no access or zoned with no take were given a weight of 1 and all other MPA classifications were given a weight of 0.5. The score of lasting special places was assessed as the ratio of the total area protected to the total area within 3nm from shore.

Table #. There are five types of conservation districts. Terrestrial conservation areas were weighted by their protective ability.

|  |  |
| --- | --- |
| Conservation District Type | Weight |
| Protective | 1.0 |
| Limited | 0.9 |
| Resource | 0.8 |
| General | 0.7 |
| Special | 0.6 |

*Data Layers & References*

*Data Gaps*

* Sacred and protected cultural and historical places (wahi pana) were suggested for inclusion in Lasting Special Places however we were not able to include them because we lacked a historical reference point. While there is data on the number protected, it is hard to know how many wahi pana have been lost over the years without an adequate reference.

**Connection to Place**

Connection to place is the 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. There were many very valuable suggestions on how to measure Connection to 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. Therefore, Connection to Place was measured through activities that take place in each place, assessed as the participation rate in ocean and coastal activities.

Where *ac* is the current participation rates for each ocean activity *i* and *ar* is the temporal reference participation rate for each activity *i.*

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 Hawaii (NOAA 2014). Unfortunately, 2014 was the first year of this assessment so there is not a baseline or reference to measure against. 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 3-4 years. This goal will be updated with future survey data.

To find opportunities to connect to place and give back please see Hawaiʻi Conservation Alliance’s Conservation Connections <http://www.conservationconnections.org/>.

*Data Layers & References*

* NOAA (2014) National Coral Reef Monitoring Program: Socioeconomic surveys of human use, knowledge, attitudes, and perceptions in Hawaii from 2014-11-11 to 2014-11-26.

*Data Gaps*

* Knowledge and records of Hawaiian place names including information on cultural practices and uses of place.

Table # Human use survey on the frequency (per year or per month? How did you calculate this?) of ocean uses of Hawaiian residents. Data from Edwards et al. 2014.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Region | Frequency | swimming/wading | snorkeling | diving(scuba or free diving) | camping | beach recreation | boating | wave riding | canoe or kayaking |
| Hawaii | Never | 17 | 39 | 66 | 46 | 19 | 67 | 63 | 69 |
| once a month | 31 | 35 | 19 | 39 | 41 | 22 | 17 | 20 |
| 2-3 times a month | 17 | 8 | 6 | 7 | 17 | 5 | 6 | 4 |
| 4 times a month or more | 35 | 17 | 9 | 8 | 23 | 7 | 14 | 7 |
| Oahu | Never | 22 | 53 | 75 | 54 | 24 | 73 | 59 | 73 |
| once a month | 33 | 28 | 14 | 37 | 40 | 18 | 20 | 17 |
| 2-3 times a month | 13 | 7 | 5 | 4 | 19 | 4 | 8 | 3 |
| 4 times a month or more | 32 | 11 | 7 | 5 | 17 | 6 | 14 | 7 |
| Maui Nui | Never | 18 | 40 | 63 | 49 | 20 | 61 | 53 | 65 |
| once a month | 23 | 31 | 19 | 36 | 34 | 27 | 18 | 21 |
| 2-3 times a month | 13 | 9 | 6 | 8 | 18 | 5 | 8 | 5 |
| 4 times a month or more | 47 | 20 | 13 | 7 | 29 | 7 | 21 | 8 |
| Kauai | Never | 14 | 40 | 62 | 40 | 13 | 61 | 51 | 57 |
| once a month | 23 | 33 | 19 | 42 | 35 | 27 | 21 | 30 |
| 2-3 times a month | 15 | 9 | 5 | 9 | 19 | 4 | 5 | 6 |
| 4 times a month or more | 47 | 18 | 13 | 9 | 34 | 8 | 23 | 7 |

**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.

C is the current (c) condition and reference (r) 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 100 meters (Lecky 2016).

Coral reef condition indicators come from the Hawaii Monitoring and Research Collaborative and combined coral reef monitoring database used to develop measurements of reef status and trends to support reef management decisions statewide, and; measure our progress toward the Sustainable Hawaii Initiative goal to effectively manage 30% of our nearshore ocean waters by 2030.

Coral reef condition is assessed as the coral reef index, a measure of coral reef health from combined indicators for % coral cover, %macroalgae, % coralline algae, and the ratio of calcifiers to non calcifiers, all fish biomass, resource fish biomass, parrotfish biomass, total fish biomass no sharks and jacks. The coral reef index scores are a rank assessment among the 42 Mokus (traditional land management areas).

Coral Reef trend – to be determined at later date, from HIMARC but for now used data from CREP 2016 Report on change in % coral cover from 2011-2012 to 2016 surveys from the Main Hawaiian Islands.

*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 classifications 3, 4, and 5 types of beaches from the National Oceanic and Atmospheric Administration Office of Response and Restoration Environmental Sensitivity Index. Beach condition is the percent of beaches remaining stable (not eroding). The beach trend is the long 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).

*Wetlands*

Wetlands are classified based on soil saturation, percent of herbaceous vegetation, trees and shrubs, locality (riverine), and salinity ([National Oceanic and Atmospheric Administration](file:///D:\Documents%20and%20Settings\eschemmel\AppData\Local\Temp\Temp1_Re%253a_expense_sharing.zip\11_Costofwetlandschange%202013%20update%2011_DEC_2013.docx#_ENREF_15), USGS NRC). Along with providing coastal protection, wetlands are important habitats which are crtitical 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 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 2010/2011 to 1992 NOAA CCAP wetlands extent within 1 km of the coastline.

*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 Hawaiʻi. 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 iʻa). Removal efforts are underway to remove and clear mangroves and restore native estuaries and fishponds (LINK to work).

*Data Layers & References*

* Coastal wetlands condition: Van Rees, CB and Reed M. 2014. Wetland loss in Hawaii since human settlement. Wetlands 34:335-350
* Coastal wetlands extent and trend: NOAA C-CAP Available: <https://coast.noaa.gov/ccapatlas/>
* Beach extent: NOAA ESI Available: <https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html>
* Beach condition and tend: Fletcher, C.H., Romine, B.M., Genz, A.S., Barbee, M.M., Dyer, Matthew, Anderson, T.R., Lim, S.C., Vitousek, Sean, Bochicchio, Christopher, and Richmond, B.M., 2012, National assessment of shoreline change: Historical shoreline change in the Hawaiian Islands: U.S. Geological Survey Open-File Report 2011–1051, 55 p., Available: http:// pubs.usgs.gov/of/2011/1051.
* Coral reef condition: NOAA Main Hawaiian Islands Report Card, in prep
* Coral reef trend: McCoy K, Heenan A, Asher J, Ayotte P, Gorospe K, Gray A, Lino K, Zamzow J, Williams I. 2017. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-17-001, 66 p. doi:10.7289/V5/DR-PIFSC-17-001, Available: https://www.pifsc.noaa.gov/cred/monitoring\_status\_reports.php.
* Coral reef extent: Lecky 2016 Ecosystem vulnerability and mapping cumulative impacts on Hawaiian reefs.

*Data Gaps*

* Infromation on fishpond extent and conidtion is needed to incorperate them into the assessment of coastal protection.
* Looking into incorporating dune data as well as beach data.
* Looking at estimates of shoreline protective ability based on slope or shoreline relief/aspect ratios.
* Information on the protective ability or importance of each habitat for coastal protection in Hawaii.
* Updated inventory on coastal wetlands and estuaries is currently being developed by the Hawaii Department of Land and Natural Resources Division of Aquatic Resources.

**Biodiversity**

The Biodiversity goal measures the conservation status of species based on two subgoals: Habitats and Species.

**Habitats**

The Habitats sub-goal of Biodiversity measures the current extent and condition of ocean and coastal habitats (*Hc*) against a reference habitat extent and condition (*Hr*). 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 100 meters (Lecky 2016).

Coral reef condition indicators come from the Hawaii Monitoring and Research Collaborative and combined coral reef monitoring database used to develop measurements of reef status and trends to support reef management decisions statewide, and; measure our progress toward the Sustainable Hawaii Initiative goal to effectively manage 30% of our nearshore ocean waters by 2030.

Coral reef condition is assessed as the coral reef index, a measure of coral reef health from combined indicators for % coral cover, %macroalgae, % coralline algae, and the ratio of calcifiers to non calcifiers, all fish biomass, resource fish biomass, parrotfish biomass, total fish biomass no sharks and jacks. The coral reef index scores are a rank assessment among the 42 Mokus (traditional land management areas).

Coral Reef trend – to be determined at later date, from HIMARC but for now used data from CREP 2016 Report on change in % coral cover from 2011-2012 to 2016 surveys from the Main Hawaiian Islands.

*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 classifications 3, 4, and 5 from the National Oceanic and Atmospheric Administration Office of Response and Restoration Environmental Sensitivity Index. Beach condition is the percent of beaches remaining stable (not eroding). The beach trend is the long-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*

Near shore soft bottom habitat extent was mapped to a depth of 100 meters (Ocean Tipping Points). 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 Ocean Tipping Points (http://www.pacioos.hawaii.edu/projects/oceantippingpoints/#data).

*Coastal Wetlands and Estuaries*

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. 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.

We combined the coastal wetland extent with estuary extent. Estuaries are defined as the transition zone where fresh water from land meets and mixes with seawater creating some of the most productive ecosystems in the world. There are many challenges to mapping and defining estuary types. Currently, there is not a complete database for estuaries in Hawaii. However, this database is currently being developed by the Hawaii Department of Land and Natural Resources Division of Aquatic Resources. For this assessment, we used the National Wetlands Inventory with the deeper water estuaries excluded as these were previously mapped out to the full near shore extent (3nm) and did not fit our classification of estuary habitats.

Since there is currently not a complete database for Hawaiian estuaries and the status of estuaries remains unknown, we applied coastal wetland condition to the wetland and estuary habitats. 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 and estuaries was assessed as the difference in area from 2010/2011 to 1992 NOAA CCAP wetlands extent within 1 km of the coastline.

*Mangroves*

Mangroves are invasive in Hawaii 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, Artisanal Fishing, Recreation, Sense of Place, and Food Provision.

*Data Layers & References*

* Coastal wetlands condition: Van Rees, CB and Reed M. 2014. Wetland loss in Hawaii since human settlement. Wetlands 34:335-350
* Coastal wetlands extent and trend: NOAA C-CAP Available: <https://coast.noaa.gov/ccapatlas/>
* Beach extent: NOAA ESI Available: <https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html>
* Beach condition and tend: Fletcher, C.H., Romine, B.M., Genz, A.S., Barbee, M.M., Dyer, Matthew, Anderson, T.R., Lim, S.C., Vitousek, Sean, Bochicchio, Christopher, and Richmond, B.M., 2012, National assessment of shoreline change: Historical shoreline change in the Hawaiian Islands: U.S. Geological Survey Open-File Report 2011–1051, 55 p., Available: http:// pubs.usgs.gov/of/2011/1051.
* Coral reef condition: NOAA Main Hawaiian Islands Report Card, in prep
* Coral reef trend: McCoy K, Heenan A, Asher J, Ayotte P, Gorospe K, Gray A, Lino K, Zamzow J, Williams I. 2017. Pacific Islands Fisheries Science Center, PIFSC Data Report, DR-17-001, 66 p. doi:10.7289/V5/DR-PIFSC-17-001, Available: https://www.pifsc.noaa.gov/cred/monitoring\_status\_reports.php.
* Coral reef extent: Lecky 2016 Ecosystem vulnerability and mapping cumulative impacts on Hawaiian reefs.
* Soft bottom condition (percent of area not impacted by dredging): Ocean Tipping Points <http://www.pacioos.hawaii.edu/projects/oceantippingpoints/#data>
* Soft bottom extent:

*Data Gaps*

* Bioindicators of coral reef health are being developed by HMARC and DAR and will be used in future assessments of coral reef health.

**Species**

Hawaiʻi has a high rate of endangered species. The latest assessment lists 501 Endangered species (77 animal) (Environmental Conservation Online System 02/13/2015). The Endangered Species Act (ESA) was established in 1973 provides 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. To assess species status, we combined information on local reef fish species status indicators (NOAA report card/ HMARC), and ESA status of marine mammals and turtles, seabirds and shorebirds, and coastal plants. We incorporated reef fish indicators even though many of Hawaiʻi’s reef fish are not considered threatened or endangered. Local indicators of reef fish populations and status are important for understanding the health of coral reefs and biodiversity and therefore were included along with reef fish species richness.

*ESA status*

Hawaiʻi does not have any listed extinct marine species, however Hawaiʻi 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 Mueseum Hawaiʻi’s Extinct Species (<http://hbs.bishopmuseum.org/endangered/extinct.html>)

*Marine Mammals & Turtles*

Marine mammals and turtles species lists were from the Marine Biogeographic assessment for the Main Hawaiian Islands. The status is based on the score given for each ESA category score with listing status from NOAA Hawaii Marine Mammal List (http://www.fisheries.noaa.gov/pr/sars/species.htm#largewhales) and US Fish and Wildlife Service (https://ecos.fws.gov/ecp/).

Table # The score given for specific ESA status.

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

Table# The ESA status of Hawaiʻi’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 |

*Seabirds and Shorebirds*

Twenty-five seabirds were identified in the Marine Biogeographic assessment for the Main Hawaiian Islands. There are at least 22 species of seabirds that breed in the Hawaiian Islands. Twenty of these species breed in the Main Hawaiian Islands (Biogeographic assessment). Five shorebirds that are found in the Main Hawaiian Islands were added to the assessment.

Table #. 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 |

Table #. 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 | Cookʻs 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 | ʻAkekeke | *Arenaria interpres* | NC |
| Shorebird | Wandering tattler | ʻŪlili | *Heteroscelus incanus* | NC |

*Coastal Plants*

Species list and status of coastal plants were sourced from Merlin 1999 and the USFWS (<https://ecos.fws.gov/ecp/)>.

Table #. List of coastal plants and ESA status.

|  |  |  |  |
| --- | --- | --- | --- |
| Common Name | Hawaiian Name | Species name | ESA Status |
| Beach spurge | Koko, ʻakoko | Chamaesyce degeneri |  |
|  | ʻĀkia, kauhi | Wikstroemia spp |  |
|  | Ahuawa | Mariscus javanicus |  |
|  | Akaakai | Schoenoplectella tabernae-montani | |
|  | Alena | Boerhavia repens |  |
|  | Degenerʻs ʻakoko | Euphorbia degeneri | V |
| Dwarf naupaka | Dwarf naupaka | Scaevola coriacsea | E |
| Pandanus | hala/Pu hala | Pandanus tectorius |  |
|  | Hau | Talipariti tiliaceus |  |
|  | Hinahina | Heliotropium anomalum | |
| Hawaiian Nama | Hinahina Kahakai | Nama sandwicensis | V |
| Moonseed | Huehue | Cocculus orbiculatus |  |
|  | Hunakai | Ipomoea imperati |  |
|  | Kalo | Colocasia esculenta |  |
| Alexandrian Laurel | Kamai | Calophyllum inophyllum | |
|  | Kaunaʻoa | Cuscuta sandwichiana |  |
|  | Kāwelu, ʻEmoloa | Eragrostis variabilis |  |
|  | Kaʻena ʻakoko | Euphorbia celastroides var. kaenana | E |
| Ivy-leaved morning glory | Koaliʻai | Ipomoea cairica |  |
| Coastal morning glory | Koaliʻawa | Ipomoea littoralis |  |
| Indian morning glory | Koaliʻawa | Ipomoea indica |  |
|  | Makaloa | Cyperus laevigatus |  |
|  | Mauʻu/ʻAkiʻaki | Fimbristylis cymosa subsp. Spathacea | |
|  | Mauʻu/ʻAkiʻaki | Fimbristylis cymosa subsp. Umbellato-capitata | |
| Hawaiian Cotton | Maʻo | Gossypium tomentosum | V |
|  | Milo | Thespesia populnea |  |
| Bastard sandalwood | Naio | Myoporum sandwicense | |
| Beach sandalwood | ʻIliahialoʻe | Santalum ellipticum | V |
| Beach pea | nanea | Vigna marina |  |
| Beach Naupaka | Naupaka kahakai | Scaevola sericea |  |
|  | Nehe | Melanthera integrifolia, Lipochaeta integrifolia | V |
|  | Nehe | Lipochaeta succulenta |  |
|  | neke Fern | Cyperus interruptus |  |
| Seaside heliotrope | Nena/Kipukai | Heliotropium curassavicum | |
| Coconut palm | Niu | Cocos nucifera |  |
| Puncture vine | Nohu | Tribulus cistoides |  |
|  | Paʻuohiʻiaka | Jacquemontia ovalifolia | |
| Beach vitex | Pohinahina | Vitex rotundifolia |  |
| Beach morning glory | Pohuehue | Ipomoea pes-caprae |  |
|  | Pōpolo | Solanum nelsonii | E |
| Caper bush, | Pua pilo or Maiapilo | Capparis sandwichiana | V |
| Prickly poppy | Pua kala | Aregemone glauca |  |
|  | Puukaa | Cyperus trachysanthos | E |
| Schiedea |  | Schiedea globosa | V |
|  | Uki | Cladium jamaicense |  |
| Water Hyssop | ʻAeʻae | Bacopa monnieri |  |
| Seashore rushgrass | ʻAkiʻaki | Sporobolus virginicus |  |
| East Maui ʻAkoko | ʻAkoko | Euphorbia celastroides var. laechiensis | E |
| Sea purslane | ʻAkulikuli | Sesuvium portulacastrum | |
|  | ʻAnaunau | Lepidium bedentatum | V |
|  | ʻEnaʻena | Psuedognaphalium sandwicensium | |
|  | ʻIhi | Portulaca molokiniensis | E |
| Pigweed | ʻIhi | Portulaca lutea |  |
| Hairy Purslane | ʻIhi | Portulaca villosa | E |
| Kilauea Portulaca | ʻIhi makole | Portulaca sclerocarpa | E |
|  | ʻIlima | Sida fallax |  |
|  | ʻOhai | Sesbania tomentosa | E |
|  | ʻOhelo kai | Lycium sandwicense |  |
|  | ʻŌhiʻa lehua | Metrosideros polymorpha | |
|  | ʻŪlei, eluehe, uʻulei | Osteomeles anthyllidifolia | |
|  | Wiliwili | Erythrina sandwicensis |  |
|  | ʻUhaloa/Hiʻaloa | Waltheria indica |  |

*Fish*

The reef fish indicator is the average of 3 components (Reef Fish Biomass, Reef Fish Sustainability, and Reef Fish Predators). 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 Layers & References*

* Coastal plant species list: Merlin, M. 1999 Hawaiian Coastal Plants.
* Coastal plant species status: USFWS Environmental Conservation Online System. Listed Plants. Available: https://ecos.fws.gov/ecp/.
* Seabird and shorebird status: 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)>.
* Marine mammal, turtle, and seabird species lists: Costa, Bryan; Kendall, Matthew (2016). Marine Biogeographic Assessment of the Main Hawaiian Islands: Synthesized physical and biological data offshore of the Main Hawaiian Islands from 1891-01-01 to 2015-03-01 (NCEI Accession 0155189). Version 1.1. NOAA National Centers for Environmental Information. Dataset. doi:10.7289/V56H4FG9 May 15, 2017
* Marine mammal and turtle status: NOAA <http://www.fisheries.noaa.gov/pr/sars/species.htm#largewhales> and US Fish and Wildlife Service https://ecos.fws.gov/ecp/.

*Data Gaps*

* Eels and other cryptic species are not accurately assessed in standard marine monitoring surveys.
* Water column, seamounts, and mesophotic habitats are considered important habitats but are not included in this assessment.
* Updated inventory on coastal wetlands and estuaries is currently being developed by the Hawaii Department of Land and Natural Resources Division of Aquatic Resources.
* Anchailine ponds were not included in this assessment because they are not found in every assessment region but they are rare and unique habitats to Hawaiʻi.

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