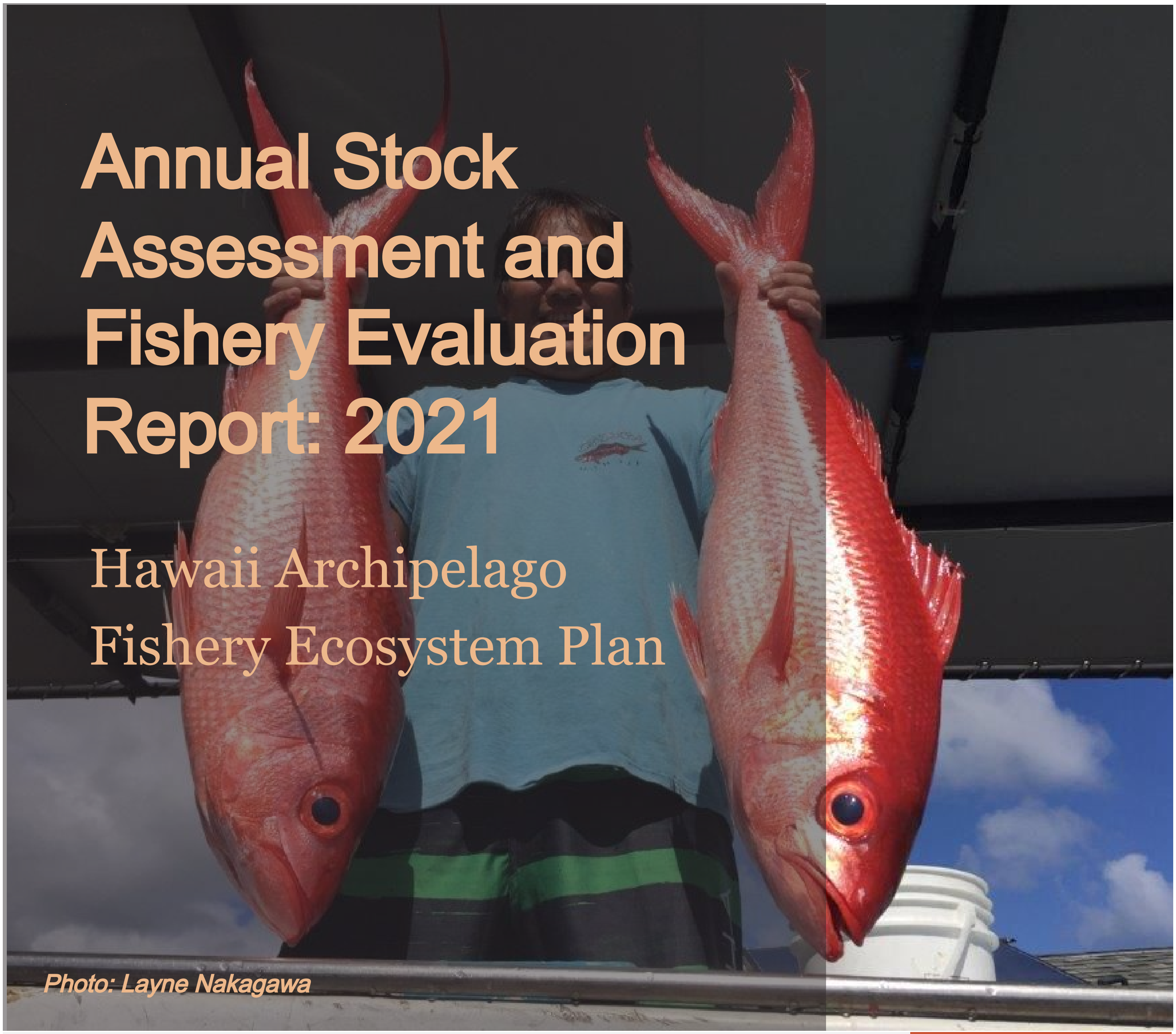
Annual Stock Assessment and Fishery Evaluation Report: 2021

Hawaii Archipelago Fishery Ecosystem Plan



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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the HAWAII ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2021 was drafted by the Fishery Ecosystem Plan Team. This is a collaborative effort primarily between the Western Pacific Regional Fishery Management Council (WPRFMC), National Marine Fisheries Service (NMFS)-Pacific Island Fisheries Science Center (PIFSC), Pacific Islands Regional Office (PIRO), Hawaii Division of Aquatic Resources (HDAR), American Samoa Department of Marine and Wildlife Resources (DMWR), Guam Division of Aquatic and Wildlife Resources (DAWR), and Commonwealth of the Mariana Islands (CNMI) Division of Fish and Wildlife (DFW).

This report attempts to summarize annual fishery performance looking at trends in catch, effort, and catch rates as well as provide a source document describing various projects and activities being undertaken on a local and federal level. The report also describes several ecosystem considerations including fish biomass estimates, biological indicators, protected species, habitat, climate change, and human dimensions. Information like marine spatial planning and best scientific information available for each fishery are described. This report provides a summary of annual catches relative to the Annual Catch Limits established by the Council in collaboration with the local fishery management agencies.

Additionally, in 2020 and 2021, there were notable impacts to fishery operations due to the 2019 novel coronavirus (COVID-19) outbreak and subsequent recovery. Impacts associated with the pandemic, its restrictions, and recovery are described in Sections 1.1 through 1.4, 2.1, 2.2, and 2.5.

Cover Image: Layne Nakagawa.

A report of the Western Pacific Regional Fishery Management Council
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The **Western Pacific Regional Fishery Management Council** acknowledges the valuable contributions of the following Plan Team members and others for drafting sections of this report:

Hawaii Division of Aquatic Resources: Jason Helyer, Paul Murakawa, and Bryan Ishida.

NMFS Pacific Islands Fisheries Science Center: Marc Nadon, Felipe Carvalho, Jenny Suter, Reka Domokos-Boyer, Joseph O'Malley, Michael Parke, Kisei Tanaka, Thomas Oliver, Melanie Abecassis, Frank Parrish, Keith Bigelow, Robert Ahrens, T. Todd Jones, Minling Pan, Danika Kleiber, Justin Hospital, and Kirsten Leong.

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v2 (7/7/2022) – In Section 1.1.2, duplicated text was removed.

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EXECUTIVE SUMMARY

As part of its five-year fishery ecosystem plan (FEP) review, the Western Pacific Regional Fishery Management Council (WPRFMC; the Council) identified its annual reports as a priority for improvement. The former annual reports have been revised to meet National Standard regulatory requirements for Stock Assessment and Fishery Evaluation (SAFE) reports. The purpose of the reports is twofold: to monitor the performance of the fishery and ecosystem to assess the effectiveness of the FEP in meeting its management objectives; and to maintain the structure of the FEP living document. The reports are comprised of three chapters: Fishery Performance, Ecosystem Considerations, and Data Integration. The Council will iteratively improve the annual SAFE report as resources allow.

The Fishery Performance chapter of this report presents descriptions of Hawaiian commercial fisheries harvesting management unit species (MUS), including Deep 7 bottomfish, non-Deep 7 bottomfish (i.e., only uku, *Aprion virescens*), and crustaceans, as well as ecosystem component species (ECS). An amendment to the Hawaii Archipelago FEP in early 2019 classified all non-Deep 7 bottomfish except for uku, all former coral reef ecosystem MUS, several crustacean MUS, and all mollusk and limu species as ECS (84 FR 2767, February 8, 2019). Species classified as ecosystem components do not require annual catch limits (ACLs) or accountability measures but are still regularly monitored in the annual SAFE report through a one-year snapshot of the ten most caught ECS, complete catch time series of nine prioritized ECS as selected by the State of Hawaii Department of Aquatic Resources (DAR), as well as trophic and functional group biomass estimates from fishery independent surveys. Existing management measures still apply to ECS. Data on precious coral MUS are not available due data confidentiality associated with the low number of federal permit holders reporting harvest.

In the Fishery Performance chapter, the data collection systems for each fishery are briefly explained. The fishery statistics are organized into summary dashboard tables showcasing the values for the most recent fishing year and the percent change between short-term (10-year) and long-term (20-year) averages. Time series of fishing parameters and species catch by gear type are also provided. Additionally, the number of federal permits and available logbook data, status determination criteria, implemented ACLs, best scientific information available, harvest extent and capacity, and administrative and regulatory actions associated with insular fisheries in the Hawaiian Archipelago are included.

For Hawaii fisheries in 2021, none of the MUS had a recent three-year average catch that exceeded their specified ACL, allowable biological catch (ABC) values, annual catch targets (ACT), or overfishing limits (OFL). Data for deepwater shrimp and precious coral were not disclosed due to data confidentiality rules that prohibit the reporting of data from less than three licensed fishers.

In 2021, the Main Hawaiian Islands (MHI) Deep 7 bottomfish fishery was generally characterized by decreasing trends in catch and effort relative to its 10- and 20-year averages (i.e., short- and long-term trends, respectively). This decline can likely be attributed to recent challenges associated with difficulty in locating normal aggregations, high shark depredation, difficult environmental conditions, and atypical fish behavior. Catches of ʻōpakapaka (*Pristipomoides filamentosus*; 57,102 lb) declined around 47% relative to its 10-year and 20-year averages. Catches for two Deep 7 bottomfish species, ehu (*Etelis carbunculus*; 29,125 lb) and gindai (*Pristipomoides zonatus*; 5,573 lb), increased relative to its short- and long-term trends, while catches for kalekale (*Pristipomoides sieboldii*; 11,163 lb) increased nearly 6% compared to their 20-year trend. The deep-sea handline gear type experienced declines in the number of licenses, trips, catch, and catch per unit effort (CPUE) relative to their short- and long-term trends. Non-deep sea handline methods catching Deep 7 bottomfish species are responsible for a much lower portion of catch but did have increases in the total number of licenses, catch, and CPUE relative to historical averages, especially for lehi (*Aphareus rutilans*) catches that show an increase of over 100% compared with historical trends.

Due to the ECS amendment to the Hawaii Archipelago FEP in 2019, the non-Deep 7 bottomfish fishery is now solely comprised of uku (*Aprion virescens*). Total catch for uku (60,358 lb) was over 37% lower than its 10-year average and 31% lower than its 20-year average, likely due to challenging fishing conditions and high shark depredation, especially when targeting uku in high number. In addition to the decrease in uku catch, there was a decrease in the number of licenses, trips, and individuals caught. Breaking down the fishery by gear type, all gears had decreases in catch relative to historical trends; however, CPUE for deep-sea handline increased relative to its 20-year average and CPUE for all gears other than handline and trolling increased relative to both of its historical averages. The number of licenses and trips (i.e., effort) for uku harvested by trolling with bait increased relative to the 20-year trend.

The Hawaii coral reef ecosystem component fishery had mixed trends in 2021, though most experienced declines in participation, catch, and effort relative to their historical averages. The most harvested ECS in 2021 were akule (*Selar crumenophthalmus*; 231,161 lb) and ‘opelu (*Decapterus macarellus*; 83,055 lb) followed by menpachi (*Myripristis* spp.; 30,937 lb), palani (*Acanthurus dussumieri*; 24,506 lb), parrotfish (multi-species; 24,090 lb), and opihi (*Cellana* spp.; 16,423 lb). In general, all 10 prioritized ECS (as selected by DAR) had decreases in the number of licenses fishing and the number of fishing trips taken except for day tako relative to its 10-year average. The number of ta‘ape caught in 2021 represented an increase relative to its 10- and 20-year trends, but pounds caught is typically a more useful metric in identifying fishery performance. The number and weight of harvested ‘opihi (limpets) increased relative to both its short- and long-term averages. Nine of the 10 prioritized Hawaii ECS had decreases in catch in 2021 relative to 2020, with the lone exception being kala (*Naso* spp.).

In 2021, the MHI crustacean fisheries, comprised of deepwater shrimp and Kona crab, had an overall decline in catch and effort relative to their short- and long-term trends. However, these two fisheries differ greatly in both their operation and catch trends and combining the crustacean MUS to analyze fishery performance may not be conducive to evaluating the state of each individual fisheries. The 2021 catch and effort data for the deepwater shrimp trapping fishery are not disclosed in this report due to rules associated with data confidentiality for statistics derived from less than three sources (i.e., fishers). In the Kona crab loop net fishery, there was declines in the number of licenses, trips, and catch relative to historical averages. However, CPUE for Kona crab increased relative to its 10- and 20-year averages, likely because effort decreased to a greater extent than catch in 2021. Data for gear types harvesting crustacean MUS other than shrimp trap and loop net indicated an increase in the number of trips relative to historical trends and an increase in catch relative to the short-term average but had notable decreases for CPUE; however, this gear type is typically comprised of Kona crab caught incidentally with other crab gears and associated values are variable year-to-year.

In addition to reported creel survey data estimates, federal logbook catch data were recently added to the report. In Hawaii, there was one federal special coral reef ecosystem permit and three shrimp permits issued in 2021, but there were no permits issued for non-commercial bottomfish, precious coral, or lobsters. None of the federal permit holders reported any catch for the fishing year.

An Ecosystem Considerations chapter was added to the annual SAFE report following the Council's review of its FEPs and revised management objectives. Fishery independent ecosystem survey data, fisher observations, socioeconomics, protected species, climate and oceanographic, essential fish habitat, and marine planning information are included in Ecosystem Considerations. In addition, a special section is included in the report this year, similar to the 2020 report, describing the impacts of COVID-19 on Hawaii archipelagic fisheries and fishing communities.

Fishery independent ecosystem data were acquired through visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) Reef Assessment and Monitoring Program (RAMP) under the Ecosystem Sciences Division (ESD) in CNMI, the Pacific Remote Island Area (PRIA), American Samoa, Guam, the MHI, and the Northwestern Hawaiian Islands (NWHI). This report describes mean fish biomass of functional, taxonomic, and trophic groups for coral reefs as well as habitat condition using mean coral coverage per island for each of these locations averaged over the past ten years. However, no surveys were conducted in 2020 or 2021 due to restrictions associated with the COVID-19 pandemic, so the data summaries in this 2021 report are identical to the 2019 report.

Life history parameters derived from otolith and gonad sampling for several bottomfish and coral reef ECS from in the MHI are also presented. These parameters include maximum age, asymptotic length, growth coefficient, hypothetical age at length zero, natural mortality, age at 50% maturity, age at sex switching, length at which 50% of a fish species are capable of spawning, and length of sex switching are provided. Available data for 18 coral reef fish species and families and eight bottomfish species are presented. In 2021, no new life history parameters were determined for any of the reported species.

The socioeconomic section begins with an overview of the socioeconomic context for the region, presents relevant socioeconomic data trends including commercial pounds sold, revenues, and prices, and lists relevant socioeconomic studies from the past year. Fish prices were generally high for Hawaii archipelagic MUS fisheries in 2021. For Hawaii MUS, the Deep-7 bottomfish complex comprised 77% of the revenue, uku comprised 21%, and crustaceans comprised just 2%. While the total number of sales from commercial marine licenses (CMLs) has continuously declined since 2015, there were 347 CMLs that reported sales data to DAR in 2021, down from 362 in 2020. In the Hawaii Deep 7 bottomfish fishery, there were 136,062 lb sold in 2021 at an average adjusted price of $8.36/lb for a revenue of $1,137,655. In the uku fishery, 52,087 lb were sold at an average adjusted price of $5.98/lb for a revenue of $311,521. There were 3,169 lb of crustacean MUS sold at an average adjusted price of $8.17/lb for a revenue of $25,881. For the top-ten harvested ECS in Hawaii, there were 458,972 lb sold for a revenue of $1,684,115 in 2021, which was less than the revenue and pounds sold for the top 10 species in 2020. Priority ECS in Hawaii had 106,730 lb sold for a revenue of $410,290 in 2021, which was also less than the revenue and pounds sold for the top 10 species (i.e., a different list composition) in 2020.

The protected species section of this report summarizes information and monitors protected species interactions in fisheries managed under the Hawaii FEP using proxy indicators such as fishing effort and shifts in gear dynamics. Protected species considered include sea turtles, sea birds, marine mammals, sharks, rays, and corals, many of which are protected under the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and/or the Migratory Bird Treaty Act (MBTA). The fisheries included in the Hawaii FEP generally have limited impacts to protected species, and currently do not have any federal observer coverage. Fishing effort and other characteristics are monitored to detect any potential change to the scale of impacts to protected species. Fishery performance data in this report indicate that there have been no notable changes in the fisheries that would affect the potential for interactions with protected species, and there is no other information that indicates that impacts to protected species have changed in recent years. In 2020, NMFS published a proposed rule to designate critical habitat for threatened coral species in the Western Pacific region (85 FR 76262, November 27, 2020). Also in 2020, it was determined that a designation of critical habitat for the oceanic whitetip shark is not prudent, as there are no areas within US jurisdiction that meet the definition of critical habitat. Lastly, in 2020, a draft recovery plan for the MHI insular distinct population segment false killer whale, and the final recovery plan is anticipated in 2021.

The climate and oceanic indicators section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Council has jurisdiction. In developing this section, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee. The primary goal for selecting the indicators used in this report was to provide fishing communities, resource managers, and businesses with climate-related situational awareness. In this context, indicators were selected to be fisheries relevant and informative, build intuition about current conditions considering changing climate, provide historical context, and recognize patterns and trends.

The trend of atmospheric concentration of carbon dioxide (CO_2) is increasing exponentially with a time series maximum at 416 ppm in 2021. Since 1989, the oceanic pH at Station ALOHA in Hawaii has shown a significant linear decrease of -0.042 pH units, or roughly a 10.2% increase in acidity ([H+]) and was 8.07 in 2020. The Oceanic Niño Index, which is a measure of the El Niño – Southern Oscillation (ENSO) phase, indicated La Niña conditions for most of 2021, with two consecutive neutral seasons punctuating the year mid-year. The Pacific Decadal Oscillation (PDO) was negative in 2021. The Accumulated Cyclone Energy (ACE) Index (x 104 kt^2) was below average in Eastern and Central North Pacific and average in the Western North and South Pacific. Annual mean sea surface temperature (SST) was 25.67 ºC in 2021, and the annual anomaly was 0.13 ºC hotter than average with some intensification in the northern part of the region and a colder than usual area southeast of the Big Island. The MHI experienced no coral heat stress in 2021. Annual mean chlorophyll-a was 0.084 mg/m^3 in 2021, with an annual anomaly that was 0.0049 mg/m3 higher than average. Precipitation in the MHI had monthly anomalies higher than average at the very beginning and ending of the year, with negative anomalies being experienced in mid-2021. The relative trend in sea level rise in the Hawaiian Archipelago continues to be 1.55 mm/year, equal to 0.51 feet in 100 years.

The essential fish habitat (EFH) review section of this report is required by the Hawaii Archipelago FEP and National Standard 2 guidelines, and it includes information on cumulative impacts to essential fish habitat in the U.S. Western Pacific region. The National Standard 2 guidelines also require a report on the condition of the habitat. In the 2017 and 2018 annual

SAFE reports, a literature review of the life history and habitat requirements for each life stage of four reef-associated crustacean species regularly landed in U.S. Western Pacific commercial fisheries was presented. This review included information on two species of spiny lobster, (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*). For the 2019 report, a review of EFH for reef-associated crustaceans in the MHI and Guam was included. There were no EFH reviews completed in 2021, and the typical benthic monitoring conducted by PIFSC has not occurred for the past two years.

The marine planning section of this report monitors activities with multi-year planning horizons and begins to track the cumulative impact of established facilities. Development of the report in later years will focus on identifying appropriate data streams to report in a standardized manner. In the Hawaii Archipelago, aquaculture, alternative energy development, and military activities are those with the highest potential fisheries impact. The special coral reef ecosystem fishing permit for the offshore aquaculture facility owned by Forever Oceans expired at the end of 2021. The next Rim of the Pacific (RIMPAC) multinational exercise will be held in summer 2022 with fewer restrictions than the 2020 RIMPAC due to the alleviation of COVID-19 restrictions.

The Data Integration chapter of this report is under development. The chapter explores the potential association between fishery parameters for uku in the MHI and an index of the El Niño Southern Oscillation (ENSO), a measure of vorticity, and a measure of surface zonal currents. Also presented is a list of recent relevant abstracts from 2021 publications associated with data integration topics. Previously, in the 2017 report, exploratory analyses were performed comparing coral reef fishery species data in the Western Pacific with precipitation, primary productivity, and sea surface temperature. The Archipelagic Fishery Ecosystem Plan Team (Plan Team) suggested several improvements to implement to the initial evaluation, which are reflected in the preliminary analysis for uku first presented in the 2018 report. Results of the evaluation for potential fishery ecosystem relationships suggested a strong inverse relationship between uku CPUE in the MHI and the ENSO index used. Uku CPUE had a strong positive relationship with surface zonal flow. While there were some potential relationships between uku fishery parameters and vorticity, they were notably weaker than those for zonal flow. A potential explanation for these results is that increased zonal flow around the MHI could increase retention of pelagic larvae for important fisheries species, such as uku, prior to their recruitment into the fishery. In continuing forward with associated analyses and presentation of results for the Data Integration chapter, work may be expanded to other top species and potentially viable ecological parameters in pursuit of standardization in future report cycles.

Plan Team members agreed to carry out the following recommendations, some of which are relevant to the Hawaii Archipelago annual SAFE report:

Regarding American Samoa and Guam BMUS catch, the Archipelagic Plan Team:

1. Recommended the Council request PIFSC, DAWR, DMWR, and the Guam and American Samoa Advisory Panels review the reported increase and decrease, respectively, of total estimated BMUS landings in 2021 to determine whether the values are statistical and/or operational anomalies associated with data collection or if the values are indicative of the actual 2021 BMUS fishery performance.

Regarding the bycatch reporting improvements in the annual SAFE reports, the Archipelagic Plan Team:

2. Endorsed the current bycatch tables, noting that fisher-reported data may be biased downward, and recommends adding a separate table to describe the type of bycatch (e.g., a top-10 ranked species list and/or top 90 percentile) that comprises the number released for non-target species in the archipelagic bycatch tables.
3. Formed a working group comprised of Keith Bigelow, Brad Gough, Matt Seeley, Brian Ishida, and Thomas Remington to address the development of the top-10 ranked species and/or top 90 percentile list approach and the issue of reporting non-target species bycatch for MUS fisheries that are targeted by multiple gear types (e.g., uku in the main Hawaiian Islands).

Regarding the territorial non-commercial fisheries module to be included in the annual SAFE reports, the Archipelagic Plan Team:

4. Recommended the following members: Marc Nadon, Danika Kleiber, Ashley Tomita, and Keith Bigelow, finalize the configuration and content for the territorial non-commercial modules, based on the commercial catch summarization procedure presented to the APT, at the upcoming intersessional meeting for incorporation in the 2022 annual SAFE reports.
5. Recommended the following members: Bryan Ishida and Paul Murakawa, and Thomas Remington work with Hongguang Ma and Thomas Ogawa in the development of the Hawaii non-commercial module utilizing a similar approach as the NOAA Saltwater Recreational Fisheries Snapshot for Western Pacific Non-Commercial Fisheries.

Regarding the estimation of total catch, the Archipelagic Plan Team:

6. Recommended the Council request PIFSC to continue the development of scripts that would enable consistency between the catch time series used in stock assessment and the annual SAFE reports to improve the monitoring of catch relative to implemented Annual Catch Limits.

Regarding the management of ecosystem component species, the Archipelagic Plan Team:

7. Recommended the PIFSC-ESD coordinate with the Council in the planning of the EBFM Workshop, incorporating the management of ECS as a thematic area. The APT notes that providing separate data streams together to inform the status of ECS in the context of EBFM would be useful to support the territorial management process. Further, the APT recommends PIFSC-ESD invite staff from Office of Sustainable Fisheries to provide guidance on the NS1 provision for designating and managing ECS as part of the workshop in combination with provisions of NS1 criteria 10.

Regarding the aquaculture management framework alternatives, the Archipelagic Plan Team:

8. Endorsed Alternative 3, which includes an expanded scope for the management framework, but notes concerns regarding the proposed 20-year duration for issued permits, non-native species, and ensuring there are appropriate monitoring plans implemented. However, the APT notes that at least a portion of these appropriate monitoring plans will be implicit through the permitting process.

Regarding the alternatives for the NWHI fishing regulations, the Archipelagic Plan Team:

9. Deferred the development of recommendations until the Office of National Marine Sanctuaries provides explicit boundaries for the proposed sanctuary relative to the

Papahānaumokuākea Marine National Monument. When the sanctuary boundaries are further defined, the Archipelagic Plan Team will revisit this topic at a future meeting.

Regarding the CNMI BMUS hierarchical cluster analysis, the Archipelagic Plan Team:

10. Recommended the Council endorse the proposed BMUS list for CNMI and include this BMUS list for consideration by the previously established Archipelagic Plan Team MSA subgroup in the development of their MSA requirement sections for the FEP amendment associated with the BMUS revisions.

Regarding the main Hawaiian Island Uku Essential Fish Habitat modeling approaches, the Archipelagic Plan Team:

11. Recommended the Council endorse both modeling approaches to formulate the habitat module of the annual SAFE report noting concerns regarding the limitations of the data inputs. The modules should include qualitative information to supplement the model results. PIFSC and Council should work towards improving the data inputs (i.e., seasonal pattern to distribution and spawning aggregation) and include commercial fishery data and size frequency data in future EFH modeling work.

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ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
A_{50}	Age at 50% Maturity
$A\Delta_{50}$	Age at 50% Sex Reversal
ABC	Acceptable Biological Catch
ACE	Accumulated Cyclone Energy
ACL	Annual Catch Limits
ACT	Annual Catch Target
AM	Accountability Measure
AVHRR	Advanced Very High Resolution Radiometer
B	Biomass
B_{FLAG}	Reference point indicating low biomass
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BOEM	Bureau of Ocean Energy Management
BRFA	Bottomfish Restricted Fishing Areas
BSIA	Best Scientific Information Available
CFEAI	Commercial Fishing Economic Assessment Index
CFR	Code of Federal Regulations
CMAP	CPC Merged Analysis of Precipitation
CML	Commercial Marine License
CMLS	Commercial Marine Licensing System
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CO-OPS	Ctr for Operational Oceanographic Products and Services
Council	Western Pacific Regional Fishery Management Council
CPC	Climate Prediction Center
CPI	Consumer Price Index
CPUE	Catch per Unit Effort
CRED	Coral Reef Ecosystem Division
CREP	Coral Reef Ecosystem Program
CREMUS	Coral Reef Ecosystem Management Unit Species
CRW	Coral Reef Watch
CSF	Community Supported Fishery
DLNR	Department of Land and Natural Resources (Hawaii)
DAR	Division of Aquatic Resources (Hawaii)
DAWR	Division of Aquatic and Wildlife Resources (Guam)
DFW	Division of Fish and Wildlife (CNMI)
DGI	Daily Growth Increments
DHW	Degree Heating Weeks
DIC	Dissolved Inorganic Carbon
DMWR	Department of Marine and Wildlife Resources (American Samoa)
DOD	Department of Defense
DPS	Distinct Population Segment
E	Effort

Acronym	Meaning
EA	Environmental Assessment
ECS	Ecosystem Component Species
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENSO	El Niño - Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
ESRL	Earth Systems Research Laboratory
F	Fishing Mortality
FL	Fork Length
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FR	Federal Register
FRMD	Fisheries Research and Monitoring Division
FRS	Fishing Report System
FTP	File Transfer Protocol
Fund	Western Pacific Sustainable Fisheries Fund
GAM	Generalized Additive Model
GIS	Geographic Information System
GLM	General Linear Modeling
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
H	Harvest
HAPC	Habitat Area of Particular Concern
HDAR	Hawaii Division of Aquatic Resources
HMRFS	Hawaii Marine Recreational Fishing Survey
HOT	Hawaii Ocean Time Series (UH)
HSEMA	Hancock Seamounts Ecosystem Management Area
HSTT	Hawaii-Southern California Training and Testing
HURL	Hawaii Undersea Research Laboratory
ITS	Incidental Take Statement
k	von Bertalanffy Growth Coefficient
L_{50}	Length at 50% Maturity
$L\Delta_{50}$	Length at 50% Sex Reversal
L_{∞}	Asymptotic Length
L_{bar}	Mean Fish Length
L_{max}	Maximum Fish Length
LAA	Likely to Adversely Affect
LIDAR	Light Detection and Ranging
LOC	Letter of Concurrence
LOF	List of Fisheries
M	Natural Mortality
MBTA	Migratory Bird Treaty Act
MEI	Multivariate ENSO Index

Acronym	Meaning
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Islands
MI	Mobile Invertebrates
MLCD	Marine Life Conservation District
MMA	Marine Managed Area
MMPA	Marine Mammal Protection Act
MODIS	Moderate Resolution Imaging Spectroradiometer
MPA	Marine Protected Area
MPCC	Marine Planning and Climate Change
MPCCC	MPCC Committee
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
MSST	Minimum Stock Size Threshold
MSU	Microwave Sounding Unit
MSY	Maximum Sustainable Yield
MUS	Management Unit Species
n	Sample Size
$N_{L\text{-}W}$	Sample Size for Length-Weigh Regression
NA	Not Applicable
NAF	No Active Fishery
NASA	National Aeronautics and Space Administration
NCADAC	National Climate Assessment and Development Advisory Cmte
NCDC	National Climatic Data Center
NCEI	National Centers for Environmental Information
n.d.	Non-Disclosure
NELHA	Natural Energy Laboratory of Hawaii Authority
NEPA	National Environmental and Policy Act
NLAA	Not Likely to Adversely Affect
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NS	National Standard
NWHI	Northwestern Hawaiian Islands
OEIS	Overseas Environmental Impact Statement
OFL	Overfishing Limits
OFR	Online Fishing Report system
ONI	Ocean Niño Index
OPI	OLR Precipitation Index
OLR	Outgoing Longwave Radiation
OTEC	Ocean Thermal Energy Conversion
OY	Optimum Yield
PCMUS	Precious Coral Management Unit Species
PDO	Pacific Decadal Oscillation
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PIAFA	Pacific Insular Area Fishery Agreement

Acronym	Meaning
PIBHMC	Pacific Islands Benthic Habitat Mapping Center
PIFSC	Pacific Island Fisheries Science Center
PIRCA	Pacific Islands Regional Climate Assessment
PIRO	Pacific Islands Regional Office
PK	Planktivorous
PMEL	Pacific Marine Environmental Laboratory
PMUS	Pelagic Management Unit Species
POES	Polar Operational Environmental Satellite
PRIA	Pacific Remote Island Areas
RAMP	Reef Assessment and Monitoring Program
RIMPAC	Rim of the Pacific
ROD	Record of Decision
ROMS	Regional Ocean Modeling System
ROV	Remotely Operated Underwater Vehicle
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SCREFP	Special Coral Reef Ecosystem Fishing Permit
SDC	Status Determination Criteria
SDM	Species Distribution Model
Secretary	Secretary of Commerce
SEEM	Social, Economic, Ecological, Management (Uncertainty)
SEIS	Supplemental Environmental Impact Statement
SFD	Sustainable Fisheries Division
SLP	Sea Level Pressure
SOEST	School of Ocean and Earth Science and Technology
SPC	Stationary Point Count
SPR	Spawning Potential Ratio
SSC	Scientific and Statistical Committee
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
SSBPR	Spawning Stock Biomass Proxy Ratio
SWAC	Seawater Air Conditioning
t_0	Hypothetical Age at Length Zero
T_{max}	Maximum Age
TA	Total Alkalinity
TAC	Total Allowable Catch
TALFF	Total Allowable Level of Foreign Fishing
TBA	To Be Assigned
TBD	To Be Determined
UFA	United Fishing Agency
UH	University of Hawaii
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
VBGF	von Bertalanffy Growth Function
WETS	Wave Energy Test Site

Acronym	Meaning
WPacFIN	Western Pacific Fishery Information Network
WPRFMC	Western Pacific Regional Fishery Management Council
WPSAR	Western Pacific Stock Assessment Review
WSEP	Weapon Systems Evaluation Program

1 FISHERY PERFORMANCE

1.1 DEEP-7 BMUS

1.1.1 Fishery Descriptions

The Deep-7 bottomfish management unit species (BMUS) group is comprised of seven deepwater bottomfish including ‘ōpakapaka (*Pristipomoides filamentosus*; pink snapper), onaga (*Etelis coruscans*; longtail snapper), ehu (*Etelis carbunculus*; ruby snapper), hapu‘upu‘u (*Epinephelus quernus*; Hawaiian grouper), kalekale (*Pristipomoides seiboldii*; Von Siebold’s snapper), gindai (*Pristipomoides zonatus*; oblique-banded snapper), and lehi (*Aphareus rutilans*; silverjaw snapper). The three most directly targeted species are ‘ōpakapaka, onaga, and ehu, which together average about 85% of the total Deep-7 catch each year. ‘Ōpakapaka in many years alone make up approximately half of the total catch. Hapu‘upu‘u, kalekale, gindai, and lehi are typically caught incidentally while targeting the three primary species.

The Deep-7 fishery is driven in large part by the traditional consumption of a whole red fish during the holiday season. Though Asian in origin, this practice is commonplace in local households of all ethnicities and seen by many as an essential element of gatherings during the holiday season. Many local families will consume red fish (primarily onaga and ehu) during New Year and/or Christmas celebrations. As a result, retail price and demand both increase markedly around this time. Deep-7, especially onaga, ‘ōpakapaka, and ehu, are also preferred by Hawaii’s restaurant and hotel sectors. Size preference varies between consumers, with local consumers preferring smaller fish that can be cooked whole and the hotel and restaurant industries preferring larger fish more conducive to filleting.

The State of Hawaii Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR) manages the deep-sea bottomfish fishery in the Main Hawaiian Islands (MHI) under a joint management arrangement with the National Marine Fisheries Service (NMFS) Pacific Islands Regional Office (PIRO) and the Western Pacific Regional Fishery Management Council (WPRFMC; the Council). The three collaborating agencies coordinate management to simplify regulations for the fishing public, prevent overfishing, and manage the fishery for long-term sustainability. This shared management responsibility is necessary as the bottomfish species complex occurs in both State and federal waters.

1.1.2 Dashboard Statistics

The collection of commercial MHI Deep-7 bottomfish fishing reports comes from two sources: paper reports received by mail, fax, or PDF copy via e-mail, and reports filed online through the Online Fishing Report system (OFR). Since federal management of the Deep-7 bottomfish fishery began in 2007, bottomfish landings have been collected on three types of fishing reports. Initially, bottomfish fishers were required to use the Monthly Fishing Report and deep-sea handline Fishing Trip Report to report their Deep-7 landings within 10 days of the end of the month. These reports were replaced by the MHI Deep-7 Bottomfish Fishing Trip Report in September 2011, after which bottomfish fishers were required to submit the trip report within five days of the trip end date. DAR implemented the OFR online website in February 2010.

The data records from fishing reports submitted online by fishers are automatically extracted and exported as daily batch text files from the OFR and uploaded by DAR and imported into the FRS database on the following business day.

The FRS processes the data, and a general error report is run daily by the data supervisor. A database assistant will contact the fisher when clarification of the data is needed. Duplicate data checks are run weekly before being researched by a database assistant. Discrepancies between dealer and catch data are checked monthly by a fisheries database assistant, who will call the fisher or dealer to clarify any discrepancies. The data supervisor then transfers both the fisheries and the dealer data to the Western Pacific Fisheries Information Network (WPacFIN) daily where data trends are created and reported weekly to Deep-7 BMUS fishery managers and stake holders.

1.1.2.1 Historical Summary

Following a minor peak in catch occurring in 2014, the MHI Deep-7 fishery has been in an overall state of decline both in terms of landings and effort. Potential causes of these declines, including the impacts of the COVID-19 pandemic, will be discussed further in Section 1.1.3. In 2021, all Deep-7 BMUS annual fishing parameters, including number of licenses, number of trips, number caught, and pounds caught, were below corresponding 10- and 20-year averages. In the DAR fishing report data, "caught" refers to all fish kept, whether for the purpose of commercial sale or personal consumption. It does not include releases or losses to depredation.

Table 1. Annual fishing parameters for the 2021 fishing year in the MHI Deep-7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages

Fishery	Parameter	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Deep-7 BMUS	No. Licenses	320	↓15.8%	↓17.1%
	Trips	2,092	↓16.3%	↓21.1%
	No. Caught	66,373	↓16.6%	↓16.5%
	Catch (lb)	164,171	↓29.5%	↓28.3%

1.1.2.2 Species Summary

ʻŌpakapaka is the most caught species, and typically makes up approximately 50% of all catch. Onaga, though a more valuable fish at market, is more difficult to catch than ʻōpakapaka and usually makes up approximately 25% of the catch. Ehu, like onaga prized during the holiday season for its bright red color, is the third most caught species at approximately 10% of catch. Kalekale, gindai, hapuʻupuʻu, and lehi each typically make up less than 6% of the total Deep-7 catch in any year.

Deep-7 species composition in Fishing Year 2021 had a relatively low (36%) contribution from ʻōpakapaka. This falls in line with challenges reported by fishers in recent years, which included difficulty in locating normal ʻōpakapaka aggregations, high shark depredation, challenging environmental conditions, and poor bite. Fishers additionally noted that when ʻōpakapaka and onaga aggregations were located, they were often composed of smaller size classes than typically seen (see Section 2.2 in WPRFMC 2021d). Some Deep-7 fishers also expressed the belief that normal aggregations of some bottomfish had shifted their behavior and/or habitat use, perhaps due to coinciding unusual current and weather patterns. Despite lowered participation and effort in the fishery, ehu and gindai had catch in excess of both their short- and long-term averages. Above average ehu catch is largely attributed to high landings in December 2020. At 6,857 lb, ehu catch in December 2020 was the highest single-month landings for the species since December 2009. Gindai, comprising less than 10% of the total Deep-7 catch, continue to show catch increases in recent years with Fishing Year 2021 landings being the highest on record.

Table 2. Annual fishing parameters by gear and species for the 2021 fishing year in the MHI Deep-7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages

Method	Species/ Fishery Indicator	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Deep-Sea Handline	‘Ōpakapaka	57,102 lb	↓47.7%	↓46.9%
	Onaga	45,309 lb	↓24.4%	↓29.8%
	Ehu	29,125 lb	↑4.88%	↑21.5%
	Hapu‘upu‘u	4,065 lb	↓51.8%	↓50.6%
	Kalekale	11,163 lb	↓13.2%	↑5.86%
	Gindai	5,573 lb	↑61.0%	↑91.2%
	Lehi	6,874 lb	↓14.7%	↓16.2%
	No. Lic.	299	↓17.6%	↓18.1%
	Trips	1,885	↓20.7%	↓25.7%
	Catch	159,212 lb	↓30.7%	↓29.6%
	CPUE	84.46 lb/trip	↓13.0%	↓6.10%
Non-Deep-Sea Handline Methods	‘Ōpakapaka	2,025 lb	↑36.1%	↑41.3%
	Onaga	49	↓46.2%	↓62.9%
	Ehu	161	↑78.9%	↓5.85%
	Hapu‘upu‘u	n.d.	-	-
	Kalekale	60 lb	↑5.26%	↓41.2%
	Gindai	74 lb	↑270%	↑15.6%
	Lehi	2,560 lb	↑108%	↑154%
	No. Lic.	39	↑21.9%	0.00%
	Trips	209	↑68.6%	↑78.6%
	Catch	4,959 lb	↑64.8%	↑64.0%
	CPUE	23.73 lb/trip	↓2.18%	↓10.9%

“-” = no available data; “n.d.” = non-disclosure due to data confidentiality.

1.1.3 Time Series Statistics

1.1.3.1 Commercial Fishing Parameters

The time series format for the Deep-7 bottomfish fishery was by the State fiscal year period (July – June) until June 1993. Prior to July 1993, the State issued and renewed the Commercial Marine License (CML) on a fiscal year basis and all licenses expired on June 30, regardless of when they were issued. During that period, each fisher received a different CML number, reducing duplicate licensee counts through June 1993. Today, all CML numbers are permanently assigned to fishers. The federal Deep-7 bottomfish fishing year, defined as September through August of the following year, was established in 2007. In order to evaluate Deep-7 bottomfish fishing trends, the time series format was re-arranged to extend from September to August beginning in September 1993. This arrangement provides a 22-year time series trend for the Deep-7 bottomfish fishery. There is a two-month segment spanning from July 1993 through August 1993 that is defined as a separate period.

Early in the time series, the Deep-7 fishery was dominated by a relatively low number of highliners that consistently produced large landings. In 1965, only 84 licensed fishers participated in this fishery. As the availability of modernized fishing boats and equipment increased in the 1970s and 1980s, so too did the number of fishers. In 1986, fishery participation peaked at 610 registered CML holders. With the expansion of the small vessel fleet, effort and landings increased accordingly and, in 1987 peaked at 596,255 pounds. In June 1993, concerns regarding the sustainability of the fishery prompted the State to establish bottomfish regulations including: bottomfish restricted fishing areas (BRFAs), vessel registration identification, and non-commercial bag limits. Since the implementation of federal Deep-7 bottomfish management, landings have been limited by an annual catch limit (ACL). In July 2019, four BRFAs including BRFA C (Makahūʻena, Kauaʻi), BRFA F (Penguin Banks), BRFA J (Mokumana-Umalei Pt, Maui), and BRFA L (Leleiwi Pt, Hawaiʻi Island) were re-opened to bottomfish fishing. On February 25, 2022, the Board of Land and Natural Resources (BLNR) voted to immediately open all remaining BRFAs to both commercial and non-commercial fishing. The BLNR found that given the management regime in place and healthy stock status of the Deep-7 complex, the benefits of the BRFAs did not outweigh their burden on fishers.

Following the peak and subsequent decline in catch in the late 1980s, the Deep-7 fishery had another (albeit much smaller) increase in catch peaking in 2014. There are multiple likely causes of this recent increase in catch including the closure of the Northwest Hawaiian Islands (NWHI) in 2009, which resulted both in certain fishers moving effort into the MHI, and increased market demand to fill the void. Economic downturn and high unemployment rate associated with the recession during that period may have also led some to enter the fishery or increase effort to offset economic losses.

In the spring of 2020, travel and gathering restrictions were implemented to combat the then-new COVID-19 pandemic. Early COVID -19 mandates and restrictions resulted in near-complete shutdowns of Hawaii’s hotel and restaurant industries as in-person dining and non-essential travel were prohibited. Deep-7 wholesale prices during the initial (most restrictive) lockdown in the spring and summer of 2020 were low, likely due in-part to the lack of demand from the restaurant and tourism-based sectors. The seasonal peak in local demand around the holiday period (November 2020 – January 2021) occurred as usual, though catch was lower than previous years. The release of COVID -19 vaccines and easing of travel restrictions resulted in the quick return of domestic travelers seeking cheap airfares. By March 2021 domestic traveler arrivals to the state were approaching pre-pandemic levels, and in June 2021 began to exceed 2019 arrivals during the same period. Deep-7 wholesale prices spiked to unprecedented levels in the summer of 2021. The return of tourists, along with disruptions to global seafood supply chains, and rising costs of other locally caught species commonly consumed by restaurants and tourism-based sectors such as ahi and opah all likely played a role in the jump in price.

Table 3. Time series of commercial fishing reports for Deep-7 BMUS reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	84	1,149	428	14,611	211,326
1966	92	1,059	414	11,040	181,868
1967	110	1,469	550	16,005	231,315
1968	121	1,194	524	12,945	195,039
1969	132	1,216	532	11,415	177,495
1970	139	1,150	528	8,482	158,195
1971	167	1,254	606	10,203	135,156
1972	218	1,929	831	19,833	228,375
1973	210	1,574	732	16,747	169,273
1974	264	2,163	938	23,976	225,767
1975	247	2,096	904	24,165	222,114
1976	308	2,321	1,011	26,364	258,852
1977	338	2,722	1,173	26,880	274,308
1978	434	2,657	1,539	41,381	307,628
1979	447	2,256	1,517	32,312	273,841
1980	461	2,861	1,435	35,098	244,075
1981	486	3,770	1,637	45,086	308,306
1982	450	3,909	1,630	46,873	329,436
1983	538	4,880	1,892	61,889	409,453
1984	555	4,483	1,806	55,952	345,326
1985	556	5,812	2,065	93,799	507,639
1986	610	5,823	2,285	101,469	524,726
1987	586	5,591	2,194	133,023	596,255
1988	553	6,058	2,135	138,109	575,345
1989	569	6,327	2,252	122,033	575,616
1990	531	5,258	1,948	90,745	459,215
1991	499	4,216	1,770	67,666	331,144
1992	488	4,511	1,845	84,427	362,517
1993.1	450	3,538	1,492	62,434	260,350
1993.2	120	373	167	7,280	28,519
1994	522	3,893	1,705	85,112	317,989
1995	526	3,919	1,711	77,776	319,940
1996	518	3,980	1,745	81,391	287,138
1997	500	4,181	1,760	81,594	297,678
1998	522	4,118	1,735	83,482	288,315
1999	433	3,012	1,431	56,755	214,180
2000	498	3,935	1,700	83,429	308,128
2001	458	3,570	1,550	70,812	262,874

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2002	393	2,920	1,355	56,438	217,231
2003	364	2,959	1,255	63,311	248,463
2004	333	2,669	1,145	57,588	209,475
2005	352	2,705	1,200	61,406	241,173
2006	352	2,287	1,053	46,154	193,191
2007	357	2,553	1,148	50,008	204,862
2008	351	2,354	1,027	49,397	196,347
2009	478	3,283	1,479	67,065	259,356
2010	461	2,804	1,229	56,942	209,277
2011	474	3,490	1,432	74,886	274,571
2012	480	3,108	1,529	68,024	227,971
2013	459	2,990	1,501	68,441	239,010
2014	423	3,182	1,496	90,296	311,209
2015	411	2,890	1,415	90,790	307,014
2016	372	2,348	1,194	74,536	260,732
2017	340	2,351	1,162	66,483	237,879
2018	341	2,169	1,102	59,332	236,119
2019	318	2,023	1,045	47,879	181,125
2020	334	1,843	1,000	45,903	161,713
2021	320	2,092	1,042	52,050	164,171
10-year avg.	**380**	**2,500**	**1,249**	**66,373**	**232,694**
20-year avg.	**386**	**2,651**	**1,240**	**62,346**	**229,044**

1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

1.1.4 Preferred Targets by Gear Type

1.1.4.1 Deep-Sea Handline

Nearly all (~99%) combined Deep-7 BMUS are caught using deep-sea handline gear. With few exceptions, deep-sea handline gear is today largely a Deep-7-specific gear type. Though traditionally literally a “handline” gear, today most deep-sea handline fishers use hydraulic or electric reels due the great depths fished and heavy lead weights. Rigging varies between fishers but commonly employs the use of a heavy lead weight and multiple baited hooks fished either near the bottom or higher in the water column depending on fish behavior and species targeted. The use of palu (chum) is common in deep-sea handline fishing and is typically delivered to depth using a palu bag attached above the hooks, or methods like “make dog” (maki-dogu) in which the lead weight, baited hooks, and chum are contained in a wrapped package and deployed at a desired depth releasing the contents.

Though fishing methods continue to evolve, with some fishers today catching Deep-7 from jet skis and even kayaks, the deep-sea handline gear type remains dominant. In Fishing Year 2021 the approximately 97% of Deep-7 were caught with deep-sea handline. The persistent dominance of this gear may suggest that it is simply the most effective way to target multiple relatively large species at great depth. Lighter methods such as inshore handline or jigging may be used by some but are likely too light to make consistent large catches.

Table 4a. DAR MHI annual Deep-7 catch summary by species and top gear, deep-sea handline, reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	ʻŌpakapaka		Onaga		Ehu		Hapuʻupuʻu	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1965	66	102,901	31	59,521	48	20,093	48	10,965
1966	76	70,651	34	63,965	47	17,607	49	11,863
1967	96	120,888	43	68,442	62	18,350	60	10,624
1968	97	84,164	62	69,504	68	19,871	58	11,304
1969	115	85,663	48	53,839	68	16,088	60	10,881
1970	114	69,538	44	43,540	62	15,870	64	19,842
1971	130	59,002	53	39,213	78	15,255	81	14,471
1972	184	117,426	71	58,673	105	21,282	112	16,659
1973	175	93,197	68	35,584	94	14,524	117	14,828
1974	220	134,838	86	43,607	113	21,113	117	14,444
1975	199	114,571	94	45,016	115	21,705	108	23,078
1976	224	101,718	118	78,684	152	28,069	140	21,236
1977	255	98,398	100	82,049	144	32,530	130	26,769
1978	345	149,538	135	66,124	191	34,385	197	27,366
1979	306	140,303	133	51,601	190	20,859	184	28,053
1980	344	147,341	161	29,889	183	15,828	182	16,984
1981	386	193,944	153	42,659	207	20,754	188	16,056
1982	369	173,764	176	65,235	232	24,088	189	20,854
1983	421	226,614	240	71,687	277	27,482	209	31,849
1984	396	153,925	240	84,615	282	35,430	208	29,010
1985	442	202,822	297	172,774	310	43,928	253	33,098
1986	481	180,087	346	195,675	371	60,969	245	27,238
1987	459	263,468	291	175,365	323	45,963	180	32,699
1988	448	301,053	275	159,975	299	43,234	197	11,094
1989	440	309,112	305	147,724	322	42,916	187	15,442
1990	419	210,224	307	143,003	312	37,720	176	14,203
1991	384	136,764	276	104,294	300	31,943	168	16,528
1992	374	173,118	253	91,813	310	31,907	167	15,136
1993.1	346	138,613	194	52,634	256	23,926	167	13,180
1993.2	85	14,511	51	5,707	60	3,059	34	1,971
1994	393	176,151	243	71,564	290	22,903	191	10,766
1995	426	178,302	236	66,199	288	26,109	228	14,932
1996	415	147,093	244	67,985	276	28,892	220	10,110
1997	377	157,591	216	59,587	263	26,598	213	13,740

Year	ʻŌpakapaka		Onaga		Ehu		Hapuʻupuʻu	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1998	386	145,776	250	68,926	299	25,154	215	11,933
1999	326	101,875	199	60,611	233	19,548	179	9,737
2000	386	166,747	251	70,984	282	26,804	209	13,084
2001	339	126,788	253	63,089	272	25,603	202	15,531
2002	291	105,788	200	60,699	223	17,029	167	8,844
2003	254	127,628	188	70,487	212	15,740	142	9,483
2004	233	88,099	186	76,519	193	20,571	130	8,255
2005	249	102,303	202	87,832	208	21,890	131	10,121
2006	245	76,968	203	75,063	206	17,980	123	7,442
2007	271	82,489	201	80,747	224	17,713	117	5,967
2008	268	94,099	197	55,825	207	17,850	130	6,209
2009	362	133,475	245	59,827	296	24,674	168	7,808
2010	325	101,986	251	57,011	297	24,061	165	7,960
2011	369	147,813	258	67,652	306	24,191	176	7,973
2012	345	109,344	261	56,084	323	27,261	157	10,384
2013	327	98,600	246	68,314	308	31,332	156	10,342
2014	324	162,369	234	75,213	276	30,408	161	10,667
2015	309	151,223	228	78,006	271	33,080	138	9,934
2016	285	133,770	203	62,411	234	30,844	122	9,718
2017	266	133,898	173	46,100	223	24,226	127	7,714
2018	258	114,413	183	66,252	220	21,483	129	9,593
2019	210	67,256	158	60,396	218	24,948	107	6,359
2020	235	63,649	158	41,333	220	24,984	104	5,602
2021	197	57,102	157	45,309	220	29,125	91	4,065
10-yr avg.	**276**	**109,162**	**200**	**59,942**	**251**	**27,769**	**129**	**8,438**
20-yr avg.	**281**	**107,614**	**207**	**64,554**	**244**	**23,970**	**137**	**8,222**

1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

Table 4b. DAR MHI annual Deep-7 catch summary by species and top gear, deep-sea handline, reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	Kalekale		Gindai		Lehi	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1965	25	14,538	19	923	21	1,256
1966	32	13,536	20	829	20	1,953

Year	Kalekale		Gindai		Lehi	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1967	34	9,584	22	769	32	2,357
1968	31	6,870	28	754	34	2,215
1969	32	4,131	23	462	41	5,924
1970	33	5,079	34	1,437	29	2,547
1971	38	4,316	36	870	34	1,789
1972	65	8,059	50	1,237	58	4,408
1973	66	5,093	47	1,260	57	4,490
1974	64	4,860	49	1,467	67	4,852
1975	79	5,885	59	1,365	78	8,043
1976	100	7,562	59	1,076	84	9,846
1977	96	7,590	66	1,143	81	6,644
1978	150	8,823	103	2,308	116	8,623
1979	126	6,602	89	2,505	114	10,076
1980	142	6,294	87	2,089	123	16,836
1981	152	7,377	108	1,654	143	19,282
1982	158	7,735	102	1,473	139	29,500
1983	192	14,080	138	2,321	193	27,766
1984	191	12,427	160	2,798	158	15,892
1985	237	22,171	181	4,598	201	25,484
1986	283	25,059	195	3,756	185	26,548
1987	263	28,154	144	3,328	214	37,503
1988	228	18,130	121	2,075	186	37,970
1989	219	11,053	132	1,830	230	45,170
1990	248	15,482	178	2,785	207	34,944
1991	245	18,874	189	3,644	166	18,970
1992	252	28,002	190	5,120	158	17,254
1993.1	245	16,954	153	3,765	154	11,177
1993.2	48	1,908	28	652	19	658
1994	236	20,252	176	4,062	129	11,987
1995	239	17,284	187	3,721	171	13,087
1996	266	19,561	156	3,159	134	9,523
1997	224	22,634	141	2,837	142	11,866
1998	239	23,084	176	3,260	150	8,701
1999	174	11,113	130	2,182	109	7,687
2000	217	15,973	170	3,215	149	10,654
2001	187	15,371	155	3,740	142	12,251
2002	155	11,036	134	2,308	114	10,896
2003	151	12,523	108	2,131	97	8,296

Year	Kalekale		Gindai		Lehi	
	No. License	**Catch (lb)**	**No. License**	**Catch (lb)**	**No. License**	**Catch (lb)**
2004	127	7,584	96	2,085	73	3,779
2005	133	7,846	98	2,028	85	6,800
2006	139	5,262	97	1,516	74	5,643
2007	146	5,646	106	2,010	80	6,851
2008	126	5,320	119	2,424	106	9,748
2009	209	9,382	169	3,557	153	15,159
2010	211	7,926	157	2,677	104	5,270
2011	213	9,804	178	2,947	115	11,058
2012	221	12,185	177	3,853	104	7,109
2013	226	12,026	184	3,423	113	11,503
2014	228	18,861	159	3,715	105	7,239
2015	222	17,623	135	2,882	130	11,338
2016	177	12,832	125	1,843	97	7,591
2017	169	10,782	121	2,130	111	8,332
2018	174	11,882	118	2,611	102	7,329
2019	169	10,184	129	3,452	79	5,844
2020	194	11,041	155	5,123	81	7,401
2021	163	11,163	146	5,573	80	6,874
10-yr avg.	**194**	**12,858**	**145**	**3,461**	**100**	**8,056**
20-yr avg.	**178**	**10,545**	**136**	**2,914**	**100**	**8,203**

1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

1.1.4.2 Non-Deep-Sea Handline Gear Types

The following section includes Deep-7 species that are harvested using gear types other than deep-sea handline, including both inshore handline and palu ahi. These gear types do occasionally harvest Deep-7 BMUS though they are typically not their primary targets. The inshore handline gear is intended to be a lighter tackle than the deep-sea handline. Though it is possible to catch Deep-7 with inshore handline gear, it is likely that some of the landings were made with the heavier tackle gear but were reported incorrectly as inshore handline. Palu ahi is a tuna handline gear primarily used to target yellowfin and bigeye tuna. Deep-7 BMUS are common bycatch for Hawaiʻi Island fishers that regularly use the palu ahi method. Some of the landings may have been taken by bottomfish fishermen who used deep-sea handline tackle but reported it as palu ahi because of the gear definition, which also involves weights and chum on a handline. In the event that DAR personnel suspect that incorrect gear types may have been recorded, fishers are contacted for verification. The fishing reports are not amended if the fisher does not respond.

The two Deep-7 species most caught with non-deep-sea handline gears are ʻōpakapaka and lehi, both of which can be found in relatively shallower waters in comparison to the other deep-7 species. ʻŌpakapaka are also the most targeted of the Deep-7 species. It is likely that some of the ʻōpakapaka caught with non-deep-sea handline gears are actually being targeted either with non-deep-sea handline gears or incorrectly reported deep-sea handline gear. Non-deep-sea handline gears in the past 20 years make up approximately 1% of all Deep-7 catch. Though there was a small increase in the catch of Deep-7 using these gears in Fishing Year 2021, it does not appear outwardly that another method is gaining popularity.

Table 5a. DAR MHI annual Deep-7 catch summary by species for non-deep sea handline methods reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	ʻŌpakapaka		Onaga		Ehu		Hapuʻupuʻu	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1965	18	662	n.d.	n.d.	11	222	3	37
1966	7	756	n.d.	n.d.	7	537	-	-
1967	3	263	-	-	-	-	n.d.	n.d.
1968	n.d.	n.d.	-	-	n.d.	n.d.	n.d.	n.d.
1969	4	281	n.d.	n.d.	4	80	n.d.	n.d.
1970	3	152	-	-	-	-	n.d.	n.d.
1971	7	108	6	57	5	26	n.d.	n.d.
1972	5	428	n.d.	n.d.	3	26	5	72
1973	7	159	n.d.	n.d.	3	37	4	17
1974	8	375	-	-	n.d.	n.d.	6	181
1975	23	1,613	3	38	6	214	10	123
1976	41	3,771	18	1,550	40	3,210	38	1,163
1977	77	7,927	21	2,704	41	3,218	36	3,345
1978	68	5,104	14	381	42	1,319	29	1,241
1979	106	5,708	21	1,426	63	1,632	61	1,503
1980	54	3,715	32	1,455	36	1,170	28	726
1981	47	3,423	14	210	28	397	27	907
1982	29	3,964	13	710	26	348	18	826
1983	61	3,233	22	1,105	36	506	30	845
1984	65	5,382	44	1,984	36	730	36	721
1985	10	850	7	1,097	8	102	12	121
1986	38	1,770	15	851	25	930	20	325
1987	34	3,947	8	304	11	3,238	15	673
1988	14	818	6	241	6	158	11	193
1989	28	1,044	16	675	11	167	9	170
1990	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	6	454
1991	-	-	-	-	-	-	11	127
1992	n.d.	n.d.	-	-	-	-	6	118
1993.1	n.d.	n.d.	-	-	-	-	6	88
1993.2	n.d.	n.d.	-	-	-	-	n.d.	n.d.

Year	ʻŌpakapaka		Onaga		Ehu		Hapuʻupuʻu	
	No. License	**Catch (lb)**	**No. License**	**Catch (lb)**	**No. License**	**Catch (lb)**	**No. License**	**Catch (lb)**
1994	n.d.	n.d.	-	-	-	-	8	126
1995	3	45	-	-	-	-	8	144
1996	7	262	-	-	n.d.	n.d.	10	129
1997	12	360	3	20	5	576	7	785
1998	12	799	n.d.	n.d.	3	37	7	68
1999	10	164	-	-	n.d.	n.d.	n.d.	n.d.
2000	10	148	-	-	n.d.	n.d.	3	19
2001	10	110	3	37	5	104	4	53
2002	7	200	n.d.	n.d.	3	71	3	62
2003	27	1,025	4	136	8	220	7	100
2004	30	1,283	6	100	11	129	8	188
2005	22	938	3	200	8	255	5	132
2006	21	1,787	4	344	6	121	4	93
2007	23	1,459	5	169	6	447	3	468
2008	20	2,118	3	62	4	412	4	370
2009	29	2,581	8	260	13	270	7	209
2010	35	757	5	201	20	271	10	203
2011	28	1,634	4	125	14	318	8	260
2012	23	540	-	-	3	59	n.d.	n.d.
2013	26	1,417	n.d.	n.d.	3	141	3	63
2014	25	1,262	3	35	5	30	n.d.	n.d.
2015	22	1,647	3	62	5	183	n.d.	n.d.
2016	16	954	n.d.	n.d.	5	19	n.d.	n.d.
2017	23	3,288	-	-	4	126	7	182
2018	14	1,471	n.d.	n.d.	7	111	n.d.	n.d.
2019	24	1,259	-	-	n.d.	n.d.	4	139
2020	17	1,015	4	103	3	21	n.d.	n.d.
2021	24	2,025	4	49	7	161	n.d.	n.d.
10-yr avg.	**21**	**1,488**	**2**	**91**	**4**	**90**	**3**	**64**
20-yr avg.	**23**	**1,433**	**4**	**132**	**7**	**171**	**4**	**136**

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.
1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

Table 5b. DAR MHI annual Deep-7 catch summary by species for non-deep-sea handline methods, reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	Kalekale		Gindai		Lehi	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
1965	8	115	n.d.	n.d.	n.d.	n.d.
1966	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1967	n.d.	n.d.	-	-	3	19
1968	n.d.	n.d.	-	-	-	-
1969	3	26	4	8	-	-
1970	n.d.	n.d.	-	-	4	129
1971	4	21	n.d.	n.d.	n.d.	n.d.
1972	5	13	4	8	3	22
1973	7	13	n.d.	n.d.	3	32
1974	n.d.	n.d.	-	-	n.d.	n.d.
1975	7	76	4	38	10	349
1976	14	345	21	133	13	489
1977	21	1,008	16	382	18	601
1978	36	1,003	34	245	43	1,168
1979	71	1,152	33	378	58	2,043
1980	25	753	27	305	33	690
1981	22	801	22	200	27	642
1982	21	315	21	142	25	482
1983	35	922	34	332	29	711
1984	25	994	35	767	36	651
1985	12	522	n.d.	n.d.	4	68
1986	27	356	3	4	18	1,158
1987	13	402	3	18	16	1,193
1988	8	129	3	6	15	269
1989	8	181	n.d.	n.d.	9	129
1990	n.d.	n.d.	-	-	-	-
1991	-	-	-	-	-	-
1992	n.d.	n.d.	-	-	-	-
1993.1	n.d.	n.d.	-	-	-	-
1993.2	-	-	-	-	-	-
1994	3	22	-	-	n.d.	n.d.
1995	n.d.	n.d.	-	-	6	92
1996	5	32	3	62	13	253
1997	7	650	5	91	22	345
1998	5	205	-	-	15	351
1999	5	224	n.d.	n.d.	27	843

Year	Kalekale		Gindai		Lehi	
	No. License	Catch (lb)	No. License	Catch (lb)	No. License	Catch (lb)
2000	7	129	n.d.	n.d.	16	357
2001	6	86	3	79	4	34
2002	5	113	n.d.	n.d.	6	159
2003	6	110	4	40	18	545
2004	7	51	3	66	20	765
2005	10	114	6	71	23	644
2006	9	86	n.d.	n.d.	23	874
2007	6	121	5	120	18	657
2008	10	212	3	404	20	1,295
2009	12	316	6	90	32	1,748
2010	15	160	12	64	24	731
2011	11	185	10	153	15	459
2012	7	67	n.d.	n.d.	19	1,050
2013	n.d.	n.d.	n.d.	n.d.	22	1,532
2014	5	53	n.d.	n.d.	27	1,328
2015	7	35	3	18	20	948
2016	n.d.	n.d.	n.d.	n.d.	12	597
2017	9	221	n.d.	n.d.	20	842
2018	5	22	n.d.	n.d.	16	919
2019	6	54	n.d.	n.d.	25	1,154
2020	3	25	-	-	15	1,365
2021	10	60	7	74	27	2,560
10-year avg.	**6**	**57**	**2**	**20**	**20**	**1,230**
20- year avg.	**7**	**102**	**4**	**64**	**20**	**1,009**

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.
1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

1.1.5 Catch Parameters by Gear Type

Deep-sea handline CPUE decreased markedly during the expansion of the small boat fleet in the 1970s and 1980s. During that period, the number of fishers and trips using deep-sea handline gear increased rapidly as new technology and availability of reliable fishing vessels increased. Following the expansion of the small boat fleet, deep-sea handline CPUE has remained relatively stable with a slight decline between 1998 and 2021.

Non-deep-sea handline catch parameters have stayed relatively consistent throughout the time series compared to those of deep-sea handline gear. Licenses, trips, and pounds caught showed the most notable increases coinciding with the expansion of the small boat fleet in the 1970s and 1980s. Presumably, this was due in part to the rapid increase in fishers using other methods like tuna handline that often catch Deep-7 incidentally. CPUE for non-deep-sea handline gears has fluctuated over the time series while staying consistently below that of deep-sea handline.

Table 6. DAR MHI annual Deep-7 BMUS CPUE (lb/trip) by dominant fishing methods reported by Fiscal Year from 1965-1993 and by Fishing Year from 1994-2021

Year	Deep-Sea Handline				Non-Deep-Sea Handline Gears			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
1965	73	1,067	210,197	197.00	27	89	1,129	12.69
1966	86	1,016	180,404	177.56	15	46	1,464	31.83
1967	107	1,449	231,014	159.43	7	21	301	14.33
1968	118	1,165	194,682	167.11	5	29	357	12.31
1969	128	1,175	176,988	150.63	12	46	507	11.02
1970	135	1,118	157,853	141.19	9	35	342	9.77
1971	163	1,219	134,916	110.68	18	36	240	6.67
1972	214	1,896	227,744	120.12	18	39	631	16.18
1973	201	1,537	168,976	109.94	22	38	297	7.82
1974	258	2,126	225,181	105.92	14	37	586	15.84
1975	238	2,040	219,663	107.68	39	62	2,451	39.53
1976	272	2,062	248,191	120.36	92	269	10,661	39.63
1977	290	2,263	255,123	112.74	105	461	19,185	41.62
1978	392	2,365	297,167	125.65	145	351	10,461	29.8
1979	379	1,901	259,999	136.77	187	380	13,842	36.43
1980	412	2,594	235,261	90.69	123	304	8,814	28.99
1981	456	3,459	301,726	87.23	105	342	6,580	19.24
1982	428	3,680	322,649	87.68	97	276	6,787	24.59
1983	500	4,574	401,799	87.84	142	363	7,654	21.09
1984	505	4,176	334,097	80	161	383	11,229	29.32
1985	538	5,682	504,875	88.86	44	138	2,764	20.03
1986	587	5,638	519,332	92.11	99	203	5,394	26.57
1987	567	5,431	586,480	107.99	65	164	9,775	59.6
1988	537	5,980	573,531	95.91	50	85	1,814	21.34
1989	541	6,229	573,247	92.03	68	107	2,369	22.14
1990	526	5,239	458,361	87.49	8	19	854	44.95
1991	492	4,198	331,017	78.85	11	21	127	6.05
1992	483	4,488	362,350	80.74	7	23	167	7.26
1993.1	445	3,525	260,249	73.83	8	13	101	7.77
1993.2	119	371	28,466	76.73	n.d.	n.d.	n.d.	n.d.
1994	515	3,871	317,685	82.07	13	25	304	12.16
1995	517	3,895	319,634	82.06	17	24	306	12.75
1996	504	3,930	286,321	72.86	34	55	816	14.84
1997	481	4,111	294,852	71.72	44	83	2,826	34.05
1998	506	4,049	286,833	70.84	35	79	1,482	18.75
1999	416	2,919	212,752	72.89	36	101	1,428	14.14

Year	Deep-Sea Handline				Non-Deep-Sea Handline Gears			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
2000	492	3,886	307,460	79.12	28	50	668	13.35
2001	446	3,529	262,372	74.35	25	45	503	11.17
2002	384	2,885	216,599	75.08	22	38	632	16.63
2003	344	2,855	246,288	86.27	45	107	2,174	20.32
2004	303	2,550	206,893	81.13	48	122	2,582	21.16
2005	319	2,595	238,820	92.03	51	111	2,353	21.2
2006	323	2,176	189,873	87.26	43	111	3,318	29.89
2007	335	2,438	201,422	82.62	40	118	3,440	29.15
2008	329	2,250	191,475	85.1	34	104	4,872	46.84
2009	450	3,133	253,883	81.04	61	153	5,474	35.78
2010	422	2,679	206,891	77.23	67	128	2,386	18.64
2011	450	3,387	271,438	80.14	47	104	3,133	30.13
2012	465	3,007	226,219	75.23	32	102	1,752	17.17
2013	439	2,858	235,538	82.41	38	133	3,472	26.11
2014	404	3,069	308,472	100.51	36	114	2,737	24.01
2015	392	2,782	304,085	109.3	33	109	2,929	26.87
2016	360	2,266	259,009	114.3	23	82	1,723	21.01
2017	325	2,226	233,181	104.75	34	126	4,698	37.28
2018	328	2,075	233,562	112.56	25	94	2,557	27.21
2019	299	1,900	178,439	93.92	38	125	2,686	21.49
2020	320	1,698	159,132	93.72	26	146	2,581	17.68
2021	299	1,885	159,212	84.46	39	209	4,959	23.73
10-year avg.	**363**	**2,377**	**229,685**	**97.12**	**32**	**124**	**3,009**	**24.26**
20- year avg.	**365**	**2,536**	**226,022**	**89.95**	**39**	**117**	**3,023**	**26.62**

1993.1 = Fiscal Year 1993; 1993.2 = July-August of calendar year 1993.

1.1.6 Bycatch Summary

BMUS bycatch when using deep-sea handline gear is generally low due to a lack of commercial bag limits and largely nonrestrictive one-pound commercial size limits for ‘ōpakapaka and onaga only. The increase in percent bycatch beginning in 2007 and peaking in 2013 is due primarily to tagging efforts by PIFSC and Pacific Islands Fisheries Group (PIFG). Tagging was performed by local fishers with CMLs, so all Deep-7 caught and released for research purposes was included in their reports. In 2021, percent bycatch for the Deep-7 fishery is below 10- and 20-year averages primarily due to a decrease in the amount of tagging activity reported by CML holders. Bycatch of non-Deep-7 when using deep-sea handline gear is consistently higher. A primary cause is that kahala (*Seriola* spp.) are frequently caught alongside Deep-7 species. Avoided by many local consumers due to their reputation for carrying ciguatera and often having parasite-laden flesh, kahala are some of the most frequently released species by commercial fishers. Though making up less than three percent of the total non-target catch using deep-sea handline, kahala make up approximately 60% of the releases.

Table 7. Time series of commercial fishing bycatch of Deep-7 BMUS and non-target species harvested with deep-sea handline, reported by Fishing Year from 2002-2021

Target Species (Deep-7 Bottomfish)							Non-Target Species (Harvested with Deep-Sea Handline)					
Year	No. Lic.	Trips	No. Reports	No. Retained	No. Released	Percent Bycatch	No. Lic.	Trips	No. Reports	No. Retained	No. Released	Percent Bycatch
2002	393	2,920	1,355	56,438	3	0.01	345	1,648	960	11,889	14	0.12
2003	364	2,959	1,255	63,311	217	0.34	342	1,795	958	13,125	3,135	19.28
2004	333	2,669	1,145	57,588	117	0.20	326	1,776	923	16,871	1,130	6.28
2005	352	2,705	1,200	61,406	156	0.25	329	1,908	977	17,452	1,643	8.6
2006	352	2,287	1,053	46,154	55	0.12	331	1,665	856	17,284	1,214	6.56
2007	357	2,553	1,148	50,008	535	1.06	328	1,969	976	24,506	1,162	4.53
2008	351	2,354	1,027	49,397	542	1.09	330	2,009	944	29,287	2,827	8.80
2009	478	3,283	1,479	67,065	507	0.75	424	2,311	1,135	26,918	1,231	4.37
2010	461	2,802	1,229	56,942	1,102	1.90	431	2,504	1,181	40,116	1,589	3.81
2011	474	3,456	1,432	74,886	2,098	2.73	458	2,583	1,280	37,560	1,787	4.54
2012	480	3,108	1,529	68,024	1,420	2.05	447	2,201	1,204	30,269	1,537	4.83
2013	459	2,990	1,501	68,441	2,010	2.85	414	2,102	1,152	29,691	1,823	5.78
2014	423	3,182	1,496	90,296	1,474	1.61	373	2,201	1,139	31,149	1,355	4.17
2015	411	2,890	1,415	90,790	1,378	1.50	355	2,065	1,106	31,395	1,709	5.16
2016	372	2,348	1,194	74,536	733	0.97	331	1,84	995	28,177	1,432	4.84
2017	340	2,351	1,162	66,483	411	0.61	314	1,923	975	29,248	1,623	5.26
2018	341	2,169	1,102	59,332	440	0.74	331	1,669	933	27,152	2,515	8.48
2019	318	2,023	1,045	47,879	630	1.30	300	1,505	881	29,100	1,671	5.43
2020	334	1,843	1,000	45,903	211	0.46	298	1,196	755	17,677	1,353	7.11
2021	320	2,092	1,042	52,050	196	0.38	276	1,453	818	30,544	1,994	6.13
10-year avg.	**380**	**2,500**	**1,249**	**66,373**	**890**	**1.25**	**344**	**1,818**	**996**	**28,440**	**1,701**	**5.72**
20-year avg.	**386**	**2,649**	**1,240**	**62,346**	**712**	**1.04**	**354**	**1,917**	**1,007**	**25,971**	**1,637**	**6.20**

1.2 *APRION VIRESCENS* (UKU; FORMERLY NON-DEEP-7 BMUS)

1.2.1 Fishery Descriptions

The uku (Aprion virescens), or green jobfish, is a valued food fish in Hawaii prized by both commercial and non-commercial fishers. Once a member of the non-Deep-7 BMUS complex, uku were previously grouped with the white/giant ulua (Caranx ignobilis), gunkan/black ulua (Caranx lugubris), butaguchi/pig-lip ulua (Pseudocaranx dentex), and yellowtail kalekale (Pristipomoides auricilla) before being removed due to the recent ecosystem component species (ECS) amendment to the Hawaii FEP in 2019 (84 FR 2767, February 8, 2019).

As a food fish, uku are like ʻōpakapaka, onaga, and other Deep-7 regarded highly for their firm and flavorful white flesh good for both cooking and raw consumption. Unlike Deep-7, uku are not typically used to fill the seasonal demand for whole fish during the holiday season due to the preference for red color. Outside of the holiday demand, uku are commonly consumed by the hotel and restaurant industries that take advantage of the low-price alternative to Deep-7 BMUS. Uku can be found across a wide range of depths and are commonly caught with a diverse array of fishing gears. Uku are typically targeted most heavily in May and June of each year, though some fishers catch them year-round in relatively high numbers.

1.2.2 Dashboard Statistics

The collection of commercial uku fishing reports comes from two sources: paper reports received by mail, fax, or PDF copy via e-mail; and reports filed online through the OFR. Uku are reported by commercial fishers on the Monthly Fishing Report, the Net, Trap, Dive Activity Report, or the MHI Deep-7 Bottomfish Fishing Trip Report.

Like the Deep-7 fishery, the time series format for the uku fishery begins with an arrangement by the State fiscal year period (July – June) until June 1993 before being reported by calendar year. Refer to data processing procedures documented in the Deep-7 BMUS section for paper fishing reports and fishing reports filed online. Database assistants and data monitoring associate will enter the paper Monthly Fishing Report information within four weeks, and the Net, Trap, Dive Activity Report and the MHI Deep-7 Bottomfish Fishing Trip Report within two business days.

1.2.2.1 Historical Summary

Like Deep-7, MHI uku fishery landings and effort and are in a state of decline following a peak 2017. Potential causes of these declines, including the impact of the COVID-19 pandemic on landings and effort will be discussed further in section 1.2.3 Time Series Statistics. In 2021, participation, catch, and effort for the MHI uku fishery were all below their corresponding short- and long-term averages.

Table 8. Annual fishing parameters for 2021 in the MHI uku fishery compared with short-term (10-year) and long-term (20-year) averages

Fishery	Parameter	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Uku	No. License	233	↓31.5%	↓29.4%
	Trips	1,005	↓34.5%	↓30.5%
	No. Caught	7,439	↓37.8%	↓29.7%
	Catch (lb)	60,358	↓37.2%	↓31.0%

1.2.2.2 Gear Summary

The MHI uku fishery as a whole is not easy to define in terms of gear use, especially in recent years. Because of the wide range of depths and habitat types frequented by uku, they are caught both intentionally and incidentally using a wide range of gears including spearfishing and shore-based casting. Deep-sea handline has historically been the dominant gear. However, other gears such as inshore handline, trolling, and casting can make up a sizable proportion of the total catch.

Table 9. Annual fishing parameters for 2021 in the MHI uku fishery compared with short-term (10-year) and long-term (20-year) averages

Method	Species/ Fishery Indicator	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Deep-Sea Handline	No. Lic.	122	↓25.6%	↓27.8%
	No. Trips	444	↓33.3%	↓37.3%
	Catch	37,942 lb	↓34.5%	↓33.1%
	CPUE	85.45 lb/trip	↓0.15%	↑7.99%
Inshore Handline	No. Lic.	27	↓50.0%	↓59.7%
	No. Trips	142	↓50.9%	↓50.9%
	Catch	5,108 lb	↓63.3%	↓58.9%
	CPUE	35.97 lb/trip	↓24.4%	↓14.8%
Troll with Bait	No. Lic.	29	↓19.4%	↑7.41%
	No. Trips	156	↓4.88%	↑23.8%
	Catch	6,697 lb	↓14.6%	↓0.80%
	CPUE	42.93 lb/trip	↓10.3%	↓21.6%
All Other Gears	No. Lic.	100	↓32.4%	↓18.7%
	No. Trips	264	↓37.3%	↓18.8%
	Catch	10,611 lb	↓35.8%	↓8.56%
	CPUE	40.19 lb/trip	↑1.49%	↑18.5%

1.2.3 Time Series Statistics

1.2.3.1 Commercial Fishing Parameters

Uku catch spiked dramatically in 1989. Though effort and participation also increased during the same time, local fishers have reported that the increase in catch was due to a sudden appearance of abundant adult uku into Hawaiian waters. Following the 1989 peak, catch quickly decreased to a low in 1996. Between 2003 and 2017, uku catch increased steadily likely due to multiple factors. Prior to 2010, a large proportion (occasionally the majority) of all uku landed annually in the State were caught in the NWHI. Following the NWHI closure in 2009, some fishers moved effort down into the MHI. MHI fishers also likely took advantage of the high market demand left by the void in catch. After multiple initial closures of the Deep-7 fishery due to exceedance of the ACL, some Deep-7 bottomfish fishermen switched to targeting uku as an alternative, further developing the fishery. Increasing market demand, especially to supply the hotel and restaurants, has also been suggested as a cause of the recent increase in catch. Between 2003 and 2018, average price per pound (adjusted for inflation) offered by registered dealers showed persistent increase. Lastly, economic downturn and increased unemployment caused by the recession starting around 2008 may have influenced new entrants into the fishery and/or more effort by existing fishers in attempts to offset economic losses.

The initial impact of the COVID-19 pandemic on the MHI uku fishery was significant as hotel and restaurant demand was almost eliminated following the lockdown in March 2020. As a result, some wholesalers limited their purchases drastically to adjust for the low demand. Unlike Deep-7, uku do not have a seasonal local demand in addition to the hotel and restaurant markets. As tourists returned to Hawaii following the easing of travel restrictions, uku wholesale prices increased. However, the fishery did not show an immediate commensurate response, with 2021 landings remaining below pre-pandemic levels. Additionally, as with the Deep-7 fishery, uku fishers have noted that shark depredation and challenging fishing conditions (e.g., unusual current patterns) have been problematic in recent years. Depredation can be especially bad when uku are targeted directly in high number, such as the fishery on Penguin Bank where a sizable proportion of MHI uku are caught annually. As a result, fishers have noted that some have moved away from targeting uku.

Table 10. Time series of commercial fishing reports for uku by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	83	627	312	1,732	68,231
1966	84	571	278	1,297	46,816
1967	108	733	366	1,911	64,215
1968	110	571	318	1,224	52,362
1969	116	716	377	1,554	54,139
1970	125	731	394	1,576	49,794
1971	137	608	356	1,712	48,418
1972	161	761	441	1,369	54,139
1973	169	767	472	1,897	46,578
1974	235	1,040	632	3,769	72,955

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1975	213	1,041	580	2,709	75,490
1976	213	934	518	2,388	69,009
1977	245	1,093	612	2,643	47,094
1978	376	1,569	1,038	4,460	94,798
1979	381	1,346	1,037	4,832	82,747
1980	362	1,488	902	5,150	63,714
1981	392	2,117	1,107	7,950	95,027
1982	384	1,994	1,107	7,664	92,871
1983	410	2,653	1,321	10,853	121,498
1984	423	2,389	1,202	12,471	141,601
1985	387	1,878	1,017	8,867	96,014
1986	307	1,346	741	4,767	67,695
1987	326	1,353	776	7,275	87,805
1988	423	2,454	1,157	14,100	185,689
1989	477	3,032	1,523	27,108	314,285
1990	454	2,205	1,267	11,720	139,387
1991	403	1,824	1,081	9,596	117,084
1992	384	1,702	1,003	8,640	93,561
1993.1	336	1,327	798	6,080	65,925
1993.2	230	696	420	2,816	34,463
1994	355	1,457	867	5,960	73,286
1995	339	1,304	789	6,131	60,128
1996	360	1,320	887	6,234	53,346
1997	420	1,705	1,006	8,099	68,003
1998	366	1,455	890	6,992	61,147
1999	379	1,493	908	11,129	90,992
2000	383	1,546	923	10,820	83,341
2001	303	1,197	768	6,749	59,095
2002	276	1,040	671	6,788	59,347
2003	282	1,028	670	5,446	46,440
2004	319	1,291	772	8,751	76,338
2005	302	1,170	741	7,891	65,242
2006	259	1,186	673	6,852	61,152
2007	280	1,265	717	8,390	69,105
2008	318	1,486	812	11,298	92,576
2009	371	1,479	906	10,091	88,196
2010	407	1,924	1,075	13,660	121,046
2011	383	1,700	986	13,048	109,432
2012	407	1,754	1,075	13,600	116,395
2013	395	1,814	1,054	14,052	121,476

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2014	379	1,679	1,004	11,687	97,003
2015	417	1,846	1,085	12,882	101,897
2016	378	1,914	1,051	15,129	118,597
2017	363	1,776	1,019	17,507	132,735
2018	286	1,235	746	10,145	75,250
2019	286	1,295	793	11,106	90,016
2020	253	1,031	626	5,952	48,038
2021	233	1,005	611	7,439	60,358
10-year avg.	**340**	**1,535**	**906**	**11,950**	**96,177**
20-year avg.	**330**	**1,446**	**854**	**10,586**	**87,532**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.2.4 Catch Parameters by Gear

The dominant gear type used to target uku is the deep-sea handline. However, since 1965 proportional catch using deep-sea handline gear has decreased as other gears become more commonly reported. This may be indicative of a shift to direct targeting with unique gears and/or techniques specifically aimed at uku. Fishers moving to target uku specifically have in some cases chosen to report as different methods. While some fishers have redefined their gear as inshore handline to reflect lighter gear weight, others have chosen to move away from the handline designation entirely and report instead with other gears, most notably casting (included in the below table as “All Other Gear Types”). CPUE for all major gear types has been increasing. This again may be an indication that direct targeting of uku with uku specialized gears and techniques is increasing over time.

Table 11. Time series of uku CPUE (lb/trip) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	Deep-Sea Handline				Inshore Handline				Troll with Bait				All Other Gear Types			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
1965	74	560	66,926	119.51	10	17	822	48.35	-	-	-	-	7	51	483	9.47
1966	78	514	46,358	90.19	4	4	50	12.5	-	-	-	-	6	53	408	7.70
1967	101	683	63,303	92.68	4	5	554	110.8	-	-	-	-	9	46	358	7.78
1968	104	510	51,715	101.4	8	13	345	26.54	-	-	-	-	8	48	302	6.29
1969	107	615	52,824	85.89	3	3	24	8	-	-	-	-	11	98	1,291	13.17
1970	115	633	48,645	76.85	3	4	20	5	-	-	-	-	10	94	1,129	12.01
1971	133	548	48,038	87.66	3	4	25	6.25	-	-	-	-	5	56	355	6.34
1972	154	663	53,336	80.45	3	3	12	4	-	-	-	-	12	95	791	8.33
1973	161	675	45,817	67.88	8	9	47	5.22	-	-	-	-	12	83	714	8.60
1974	216	969	72,132	74.44	7	10	158	15.8	-	-	-	-	21	61	665	10.90
1975	191	947	74,325	78.48	16	23	331	14.39	-	-	-	-	24	71	834	11.75
1976	166	732	63,048	86.13	42	97	2,453	25.29	-	-	-	-	33	106	3,508	33.09
1977	187	716	36,177	50.53	60	211	7,792	36.93	-	-	-	-	49	166	3,125	18.83
1978	303	1097	75,501	68.82	134	298	14,348	48.15	-	-	-	-	49	181	4,949	27.34
1979	248	857	67,218	78.43	211	431	12,673	29.4	-	-	-	-	26	70	2,856	40.80
1980	290	1196	57,753	48.29	71	113	1,836	16.25	-	-	-	-	78	181	4,125	22.79
1981	338	1763	90,177	51.15	67	110	1,198	10.89	-	-	-	-	59	247	3,652	14.79
1982	354	1752	88,334	50.42	43	64	582	9.09	-	-	-	-	40	180	3,955	21.97
1983	368	2451	115,347	47.06	46	67	581	8.67	-	-	-	-	56	141	5,570	39.50
1984	381	2152	134,986	62.73	53	76	1,169	15.38	-	-	-	-	69	166	5,446	32.81
1985	361	1785	94,464	52.92	4	4	207	51.75	-	-	-	-	33	89	1,343	15.09
1986	270	1220	63,788	52.29	22	52	2,323	44.67	-	-	-	-	47	75	1,584	21.12
1987	247	988	61,460	62.21	91	245	11,695	47.73	-	-	-	-	53	120	14,650	122.08
1988	350	2091	167,959	80.32	91	186	10,401	55.92	-	-	-	-	59	177	7,329	41.41

Year	Deep-Sea Handline				Inshore Handline				Troll with Bait				All Other Gear Types			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
1989	424	2667	298,435	111.9	75	162	4,532	27.98	-	-	-	-	77	209	11,318	54.15
1990	375	1799	122,703	68.21	78	218	2,653	12.17	-	-	-	-	91	189	14,031	74.24
1991	322	1427	103,311	72.40	106	236	4,719	20.00	-	-	-	-	75	165	9,054	54.87
1992	281	1119	68,813	61.50	127	441	18,850	42.74	-	-	-	-	73	144	5,898	40.96
1993.1	222	808	54,507	67.46	114	354	8,286	23.41	-	-	-	-	60	166	3,132	18.87
1993.2	172	508	30,667	60.37	45	90	1,740	19.33	-	-	-	-	40	99	2,056	20.77
1994	259	1026	59,416	57.91	93	275	11,415	41.51	-	-	-	-	74	158	2,455	15.54
1995	249	931	52,322	56.20	76	222	4,836	21.78	-	-	-	-	78	152	2,970	19.54
1996	223	743	41,024	55.21	140	400	8,612	21.53	-	-	-	-	87	179	3,710	20.73
1997	231	912	47,676	52.28	189	634	17,575	27.72	-	-	-	-	87	161	2,752	17.09
1998	224	771	44,129	57.24	146	550	14,049	25.54	-	-	-	-	69	134	2,970	22.16
1999	236	836	76,039	90.96	153	508	11,700	23.03	-	-	-	-	61	150	3,253	21.69
2000	246	914	67,280	73.61	143	485	12,948	26.7	-	-	-	-	71	148	3,113	21.03
2001	185	700	38,547	55.07	115	356	15,369	43.17	-	-	-	-	62	143	5,179	36.22
2002	176	618	44,885	72.63	81	279	9,765	35.00	9	17	404	23.74	69	127	4,294	33.81
2003	141	576	31,930	55.43	78	209	6,454	30.88	17	67	4,674	69.75	86	177	3,382	19.11
2004	155	721	56,942	78.98	94	307	7,871	25.64	23	93	7,395	79.52	86	170	4,130	24.3
2005	164	655	46,370	70.79	71	217	5,378	24.78	18	90	6,768	75.20	89	209	6,726	32.18
2006	147	665	39,997	60.15	51	230	9,554	41.54	12	76	6,171	81.20	80	216	5,430	25.14
2007	153	684	45,566	66.62	66	276	11,488	41.62	12	112	7,500	66.96	78	193	4,552	23.58
2008	177	826	63,152	76.46	84	319	12,983	40.7	17	123	10,962	89.12	95	220	5,480	24.91
2009	205	845	66,618	78.84	90	291	10,677	36.69	16	61	2,789	45.72	118	284	8,112	28.56
2010	221	1068	83,633	78.31	100	367	17,152	46.74	31	118	5,890	49.92	135	373	14,370	38.53
2011	206	868	76,826	88.51	96	401	18,232	45.47	28	114	4,076	35.75	140	319	10,298	32.28
2012	206	767	75,310	98.19	90	409	19,789	48.38	32	146	5,778	39.57	144	435	15,518	35.67
2013	184	799	76,271	95.46	80	332	18,964	57.12	44	218	7,945	36.44	169	470	18,297	38.93

Year	Deep-Sea Handline				Inshore Handline				Troll with Bait				All Other Gear Types			
	No. Lic.	**Trips**	**Catch (lb)**	**CPUE**	**No. Lic.**	**Trips**	**Catch (lb)**	**CPUE**	**No. Lic.**	**Trips**	**Catch (lb)**	**CPUE**	**No. Lic.**	**Trips**	**Catch (lb)**	**CPUE**
2014	163	715	56,801	79.44	67	276	12,156	44.04	45	196	8,259	42.14	167	492	19,788	40.22
2015	178	779	65,083	83.55	64	346	12,591	36.39	49	172	6,344	36.88	200	550	17,879	32.51
2016	181	822	73,362	89.25	59	308	11,518	37.39	33	222	12,721	57.3	173	565	20,997	37.16
2017	201	901	85,567	94.97	45	318	16,954	53.32	35	151	13,717	90.84	153	409	16,496	40.33
2018	138	469	34,014	72.52	34	273	17,363	63.60	27	132	7,404	56.09	140	363	16,469	45.37
2019	145	529	48,327	91.36	38	259	16,460	63.55	41	142	5,390	37.95	131	370	19,840	53.62
2020	121	402	26,381	65.62	33	227	8,112	35.73	29	108	4,132	38.26	107	294	9,413	32.02
2021	122	444	37,942	85.45	27	142	5,108	35.97	29	156	6,697	42.93	100	264	10,611	40.19
10-yr avg.	**164**	**663**	**57,906**	**85.58**	**54**	**289**	**13,902**	**47.55**	**36**	**164**	**7,839**	**47.84**	**148**	**421**	**16,531**	**39.60**
20-yr avg.	**169**	**708**	**56,749**	**79.13**	**67**	**289**	**12,428**	**42.23**	**27**	**126**	**6,751**	**54.76**	**123**	**325**	**11,604**	**33.92**

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.
1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.2.5 Bycatch Summary

Uku percent bycatch is typically low (<2%) since the only regulation limiting commercial catch is a one-pound minimum size. Uku less than one pound can be retained for personal consumption. Percent bycatch has seen steady increase since 2002. One contributing factor is the increasing use of inshore handline gear over time. In the past ten years, inshore handline gear landed approximately 15% of the total uku catch yet contributed about 50% of all releases. Peak uku percent bycatch in 2020 is likely also the result of COVID-19 restrictions limiting market demand. Individual fishers noted that during the most restrictive lockdown periods, local dealers were drastically limiting the amount of uku they were willing to purchase per day. Percent bycatch for uku in 2021 was relatively high, though it should be noted still low in comparison to other fisheries.

In comparison to other species targeted with similar gears, uku are retained at a slightly higher rate. This is due in part to the fact that commonly released species such as kahala and sharks are caught with similar gears and drive the non-uku bycatch rates up slightly. However, it should be noted that the majority of the non-target species included in the below table were caught while not targeting uku (e.g., inshore handline for akule and deep-sea handline for Deep-7).

Table 12. Time series of commercial fishing bycatch of uku and non-target species harvested with deep-sea handline, inshore handline, or casting, reported by Fishing Year from 2002-2021

	Target Species (Uku)						Non-Target Species (Harvested with Deep-Sea Handline, Inshore Handline, or Casting)					
Year	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**
2002	276	1,040	671	6,788	12	0.18	794	9,325	3,144	353,966	2,105	0.59
2003	282	1,028	670	5,446	2	0.04	696	8,819	2,833	686,361	4,883	0.71
2004	319	1,291	772	8,751	44	0.50	692	8,473	2,755	586,526	4,161	0.70
2005	302	1,170	741	7,891	12	0.15	642	6,964	2,433	430,528	3,654	0.84
2006	259	1,186	673	6,852	27	0.39	633	7,035	2,410	554,901	3,124	0.56
2007	280	1,265	717	8,390	13	0.15	675	7,637	2,640	590,755	3,748	0.63
2008	318	1,486	812	11,298	27	0.24	823	8,288	2,910	564,609	5,908	1.04
2009	371	1,479	906	10,091	52	0.51	921	10,603	3,680	725,166	7,613	1.04
2010	407	1,924	1,075	13,660	81	0.59	893	10,157	3,618	689,383	10,223	1.46
2011	383	1,695	986	13,048	148	1.12	865	8,884	3,243	625,634	8,115	1.28
2012	407	1,753	1,075	13,600	132	0.96	903	8,855	3,475	589,752	8,135	1.36
2013	395	1,811	1,054	14,052	134	0.94	897	8,890	3,444	610,168	9,062	1.46
2014	379	1,678	1,004	11,687	169	1.43	857	8,473	3,428	604,623	10,844	1.76
2015	417	1,844	1,085	12,882	208	1.59	809	7,844	3,123	599,997	9,639	1.58
2016	378	1,908	1,051	15,129	154	1.01	736	7,084	2,849	497,611	8,243	1.63
2017	363	1,771	1,019	17,507	100	0.57	718	7,145	2,916	502,824	10,922	2.13
2018	286	1,222	746	10,145	119	1.16	651	5,752	2,428	458,744	9,759	2.08
2019	286	1,283	793	11,106	171	1.52	637	5,732	2,485	444,122	7,663	1.70
2020	253	1,026	626	5,952	147	2.41	609	4,651	2,153	409,912	6,595	1.58
2021	233	998	611	7,439	148	1.95	563	4,403	1,988	347,127	7,210	2.03
10-year avg.	**340**	**1,529**	**906**	**11,950**	**148**	**1.35**	**738**	**6,883**	**2,829**	**506,488**	**8,807**	**1.73**
20-year avg.	**330**	**1,443**	**854**	**10,586**	**95**	**0.87**	**751**	**7,751**	**2,898**	**543,635**	**7,080**	**1.31**

1.3 CORAL REEF ECOSYSTEM COMPONENTS

1.3.1 Fishery Descriptions

Hawaii's inshore commercial fisheries cover a broad range of species and gear types. Top-5 gears (by landings) used to target these inshore non-MUS include gill nets, inshore handline, seine nets, spearfishing, and lift (ʻopelu) nets. Overwhelmingly these inshore resources are consumed locally, with exports occurring very rarely. Some species such as opihi (limpets) and ula (spiny lobsters) are prized delicacies and fetch high retail prices. Others like palani, nenue, pualu are often found in markets priced below imports. These species fill an important niche in Hawaii's small independent fish markets, offering fresh local fish at an affordable price.

In 2018, the Council drafted an Amendment 5 to the Hawaii Archipelago FEP that reclassified a large number of MUS as Ecosystem Component Species (ECS; WPRFMC 2018). The final rule was posted in the Federal Register in early 2019 (84 FR 2767, February 8, 2019). This amendment reduced the number of MUS from 173 species/families to 20 in the Hawaii FEP. All former coral reef ecosystem management unit species (CREMUS) were reclassified as ECS that do not require ACL specifications or accountability measures but are still to be monitored regularly to prioritize conservation and management efforts and to improve efficiency of fishery management in the region. All existing management measures, including reporting and record keeping, prohibitions, and experimental fishing regulations apply to the associated ECS.

As a continued effort to monitor ECS, a one-year reflection of the top ten harvested ECS (by weight) is included in this report. Additionally, DAR selected ten species reclassified as ECS that are still of priority to the State for regular monitoring. These prioritized ECS species are ʻopihi (*Cellana* spp.; limpet), ula (*Panulirus* spp.; spiny lobster), kūmū (*Parupeneus porphyreus*; whitesaddle goatfish), omilu (*Caranx melampygus;* bluefin trevally), uhu (family Scaridae; parrotfish), he'e (*Octopus cyanea*; day tako), kala (*Naso* spp.; horned unicornfish), nenue (*Kyphosus* spp.; chubs), manini (*Acanthurus triostegus*; convict tang), and taʻape (*Lutjanus kasmira*; bluestripe snapper). Time series of commercial fishing reports for these species are included in this report. These ten species are important not only commercially but recreationally and culturally as well. There is no current data gathering system for recreational or subsistence catch of these ten species other than the Hawaii Marine Recreational Fishers Survey (HMRFS), which conducts creel surveys around the State to collect catch data from recreational and subsistence fishers.

1.3.2 Dashboard Statistics

The collection of commercial ECS finfish and invertebrate fishing reports comes from two sources: paper reports received by mail, fax, or PDF copy via e-mail, and reports filed online through the OFR. The ECS are reported by commercial fishers in the Monthly Fishing Report, the Net, Trap, Dive Activity Report, or the MHI Deep-7 Bottomfish Fishing Trip Report.

Similar to the Deep-7 bottomfish, the time series format for the ECS fishery begins with an arrangement by the State fiscal year period (July – June) until June 1993 before being reported by calendar year. Refer to data processing procedures documented in the Deep-7 BMUS section for paper fishing reports and fishing reports filed online (see Section 1.1.2). Database assistants and the data monitoring associate will enter the paper Monthly Fishing Report information within four weeks, and the Net, Trap, Dive Activity Report and the MHI Deep-7 Bottomfish Fishing Trip Report within two business days.

In terms of catch parameters (pieces and pounds), the reliability of each can vary depending on the size, quantity, and collection techniques associated each species. Pieces caught is generally seen as less accurate of a measure of catch in that some fishers have a practice of providing only a rough estimate of number or occasionally omit this information altogether. This is especially common in species that are small in size and/or caught in large quantities. Whereas counting small and/or numerous catches is time consuming, weighing is simple and ensures that dealer records (which rely on weight as a primary measure of purchase) will be similar to what is reported on fishing reports. In most cases, DAR recommends using weight over pieces as a measure of catch.

1.3.2.1 2021 Most Harvested ECS

As usual, akule dominated 2021 ECS fisheries. Akule are consistently the top species harvested in the MHI due to their ability to be caught in large quantities with both net and hook and line gears and persistent high demand from local consumers. Between years, the top-10 ECS ranking can vary in composition as fishing activity, including that of specific highliners, changes. However, the species most harvested in 2021 are all commonly found in the top ranks in most years.

Table 13. Top ten landed species (lb) in Hawaii ECS fisheries in 2021

Species	No. Licenses	Trips	Catch (lb)
Selar crumenophthalmus (akule)	174	1,295	231,161
Decapterus macarellus (‘opelu)	93	957	83,055
Myripristis spp. (menpachi)	138	753	47,706
Lutjanus kasmira (ta‘ape)	142	702	30,937
Acanthurus dussumieri (palani)	42	350	24,506
Parrotfish spp. (uhu)	44	418	24,090
Cellana spp. (opihi)	14	222	16,423
Mulloidichthys vanicolensis (red weke)	41	159	12,609
Naso annulatus (kala)	23	123	12,486
Portunus sanguinolentus (kuahonu crab)	3	99	11,876

1.3.2.2 Prioritized Species Summary

With the exception of ‘opihi, all prioritized ECS had catch in pounds below their short-and long-term averages. As previously noted, for fisheries where target species are small and/or numerous, catch in pounds is seen as a more reliable measure than catch in pieces as fishers will commonly omit such information or provide only rough estimates. Increases in effort and participation in 2021 in comparison to short and long term trends were only seen in he‘e or day octopus.

Table 14. Annual fishing parameters for 2021 for prioritized MHI ECS designated by DAR compared with short-term (10-year) and long-term (20-year) averages

Species	Fishery Indicator	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
‘Opihi	No. Lic.	14	↓26.3%	↓33.3%
	Trips	222	↓8.64%	↓11.2%
	No. Caught	108,060	↑118%	↑253%
	Catch	16,423 lb	↑3.65%	↑12.4%
Lobster	No. Lic.	6	↓53.9%	↓68.4%
	Trips	76	↓55.6%	↓64.0%
	No. Caught	1,187	↓61.3%	↓68.9%
	Catch	1,945 lb	↓68.7%	↓75.1%
Kūmū	No. Lic.	28	↓56.3%	↓62.2%
	Trips	94	↓67.8%	↓74.7%
	No. Caught	424	↓78.1%	↓79.2%
	Catch	589 lb	↓79.7%	↓83.3%
Omilu	No. Lic.	66	↓41.1%	↓44.1%
	Trips	211	↓40.1%	↓42.0%
	No. Caught	469	↓56.2%	↓57.6%
	Catch	3,401 lb	↓44.7%	↓48.0%
Uhu	No. Lic.	44	↓39.7%	↓47.6%
	Trips	418	↓46.0%	↓51.7%
	No. Caught	5,083	↓53.3%	↓52.6%
	Catch	24,090 lb	↓50.7%	↓48.3%
He‘e (Day tako)	No. Lic.	41	↑7.89%	↓35.9%
	Trips	206	↑0.49%	↓67.1%
	No. Caught	1,521	↓33.8%	↓79.5%
	Catch	4,360 lb	↓37.0%	↓80.0%
Kala	No. Lic.	23	↓48.9%	↓57.4%
	Trips	123	↓63.2%	↓67.6%
	No. Caught	3,345	↓30.1%	↓33.2%
	Catch	12,486 lb	↓38.2%	↓42.2%
Nenue	No. Lic.	26	↓53.6%	↓60.0%
	Trips	136	↓55.3%	↓58.3%
	No. Caught	2,928	↓32.6%	↓53.9%
	Catch	8,468 lb	↓42.7%	↓56.2%
Manini	No. Lic.	32	↓37.3%	↓47.5%
	Trips	306	↓36.6%	↓46.5%
	No. Caught	20,889	↓8.81%	↓15.0%
	Catch	8,663 lb	↓24.0%	↓31.4%
Ta‘ape	No. Lic.	142	↓35.7%	↓36.3%
	Trips	702	↓33.8%	↓38.1%
	No. Caught	62,198	↑33.5%	↑40.1%

Species	Fishery Indicator	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
	Catch	30,937	↓3.57%	↓13.1%

1.3.3 Prioritized Species Statistics

A common catch trend among inshore species in the past 20 years is a peak occurring between 2010 and 2015. This trend can be seen in a diverse array of fisheries including those using handpick, net, hook and line, and spearfishing gear types. This is thought to be in part due to the 2008 recession. In times of economic downturn and high unemployment, an increase in the number of individuals participating in these fisheries is common as some turn to commercial fishing to supplement their incomes or replace lost jobs. For many of these species, catch tracks similarly with statewide rates of unemployment. Unlike offshore boat-based fisheries, the targeting of inshore species requires minimal initial investment and therefore the greatest ease of entry. Accordingly, it is likely that the decreasing unemployment rates post-2011 influenced the declining participation, effort, and catch in many of these fisheries.

Many ECS fisheries may have been largely spared from the effects of COVID-19 restrictions since they are purchased almost entirely by locals for home consumption. Some ECS fisheries like ‘opihi, kūmū, kala, manini, and ta‘ape even saw increases in catch between 2019 and 2020. Job loss and economic insecurity may have driven some of this increase, though its total impact is unknown.

Table 15. Time series of commercial fishing reports for all ‘opihi (*Cellana* spp.; limpet) species reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	14	239	66	-	16,651
1966	13	171	61	-	13,989
1967	40	779	176	-	36,000
1968	26	450	112	-	23,185
1969	36	413	127	-	23,818
1970	41	392	133	1,810	20,446
1971	46	368	148	1,929	17,229
1972	44	268	117	5	16,739
1973	46	257	121	600	17,169
1974	51	351	147	66,163	19,558
1975	46	333	140	115	14,396
1976	52	327	151	13,560	19,052
1977	60	306	157	750	13,969
1978	54	231	155	15,622	15,119
1979	51	182	158	-	14,146
1980	49	230	119	28	10,617
1981	36	218	87	30	7,889

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1982	36	190	82	1	7,725
1983	37	190	78	-	6,675
1984	40	181	95	61	8,548
1985	36	285	95	151	13,512
1986	64	289	141	1,066	12,426
1987	91	563	222	200	17,949
1988	71	334	145	618	12,277
1989	68	319	143	40	11,685
1990	56	179	110	-	7,848
1991	58	212	114	-	7,680
1992	55	315	130	-	9,271
1993.1	39	194	87	-	5,672
1993.2	26	138	55	-	4,628
1994	42	435	137	-	11,444
1995	56	461	151	-	13,098
1996	41	371	115	-	12,079
1997	51	299	125	1,106	10,979
1998	50	289	128	110	13,936
1999	43	406	112	-	10,774
2000	31	415	103	-	9,950
2001	24	356	96	710	12,938
2002	32	427	105	11,300	13,373
2003	23	341	106	9,980	11,714
2004	15	193	57	2,234	8,087
2005	12	181	42	372	7,380
2006	19	143	51	7,919	10,264
2007	20	182	63	5,508	6,911
2008	27	202	67	3,692	10,530
2009	25	294	81	16,716	22,773
2010	34	340	97	16,570	26,747
2011	25	261	78	41,370	16,053
2012	28	289	96	8,750	18,377
2013	18	362	86	6,893	25,816
2014	27	333	91	10,419	22,417
2015	17	248	82	14,126	14,211
2016	16	156	77	39,166	9,125
2017	16	198	80	72,820	11,131
2018	18	231	94	76,541	13,368
2019	20	182	91	50,631	11,018
2020	11	205	67	108,529	16,558

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2021	14	222	67	108,060	16,423
10-year avg.	**19**	**243**	**83**	**49,594**	**15,844**
20-year avg.	**21**	**250**	**79**	**30,580**	**14,614**

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.
1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 16. Time series of commercial fishing reports for all lobster species from reported by Calendar Year from 2003-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2003	38	205	90	3,645	7,404
2004	24	278	75	4,382	8,451
2005	27	321	73	5,844	11,633
2006	18	247	62	3,770	7,669
2007	18	224	64	4,028	8,246
2008	19	261	60	5,242	11,510
2009	28	353	80	6,832	14,512
2010	28	300	77	5,727	12,094
2011	26	257	73	5,190	10,646
2012	25	257	72	4,841	9,808
2013	14	250	57	5,091	10,949
2014	18	227	53	4,883	10,524
2015	14	141	41	2,941	5,922
2016	14	159	42	2,247	4,519
2017	14	182	46	2,806	5,569
2018	8	157	36	2,585	5,015
2019	9	126	30	2,111	4,207
2020	9	134	28	1,991	3,711
2021	6	76	18	1,187	1,945
10-year avg.	**13**	**171**	**42**	**3,068**	**6,217**
20-year avg.	**19**	**211**	**55**	**3,816**	**7,816**

Table 17. Time series of commercial fishing reports for kūmū (*Parupeneus porphyreus*; white saddle goatfish) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	62	700	234	1,874	12,060
1966	51	546	201	2,900	8,515
1967	62	575	216	3,826	9,599
1968	51	482	179	3,570	8,599
1969	72	649	240	3,215	8,616
1970	78	635	248	2,883	8,408

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1971	96	598	270	1,649	7,205
1972	98	583	274	2,674	6,394
1973	99	617	296	2,731	8,813
1974	109	629	290	3,521	7,894
1975	88	630	255	2,585	7,033
1976	104	639	285	3,037	7,367
1977	117	887	380	2,629	10,373
1978	168	897	519	3,731	15,435
1979	163	620	488	3,133	15,429
1980	149	810	439	2,544	13,978
1981	143	1,192	465	4,891	15,235
1982	119	980	411	3,024	10,164
1983	119	771	361	2,145	8,728
1984	143	814	386	2,074	7,150
1985	134	941	396	2,015	10,866
1986	117	719	331	1,194	6,760
1987	129	782	368	2,290	7,919
1988	121	739	316	2,164	8,288
1989	137	763	373	1,788	7,959
1990	122	616	327	1,564	5,903
1991	149	650	374	1,193	5,335
1992	118	799	343	1,746	6,943
1993.1	117	760	334	935	6,628
1993.2	79	335	159	595	2,811
1994	132	575	336	1,151	4,037
1995	151	784	391	1,174	6,246
1996	139	665	386	839	5,284
1997	131	637	367	1,127	5,118
1998	127	642	347	2,103	5,357
1999	108	560	319	1,436	4,117
2000	110	535	305	1,646	5,133
2001	104	532	276	1,648	4,539
2002	98	558	283	1,266	3,917
2003	91	364	223	1,218	2,585
2004	82	380	231	1,255	2,233
2005	71	295	181	958	2,585
2006	56	228	148	673	1,471
2007	61	315	174	971	1,759
2008	71	297	192	918	2,335
2009	111	555	305	2,612	5,483

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2010	101	841	359	5,503	9,832
2011	96	665	305	6,144	9,564
2012	106	679	333	6,216	8,451
2013	102	571	287	4,499	7,179
2014	91	438	236	2,945	4,418
2015	70	276	177	1,668	2,708
2016	59	291	160	1,114	2,069
2017	61	205	133	951	1,371
2018	45	144	105	538	751
2019	43	99	75	357	553
2020	35	127	95	629	870
2021	28	94	70	424	589
10-year avg.	**64**	**292**	**167**	**1,934**	**2,896**
20-year avg.	**74**	**371**	**204**	**2,043**	**3,536**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 18. Time series of commercial fishing reports for omilu (*Caranx melampygus*; bluefin trevally) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	26	155	75	383	3,633
1966	25	138	61	125	2,114
1967	25	109	60	463	1,851
1968	23	129	55	763	4,397
1969	32	259	81	202	6,876
1970	26	236	71	273	4,545
1971	20	161	60	410	2,912
1972	19	83	50	159	815
1973	19	76	46	35	907
1974	19	122	55	110	1,841
1975	22	118	55	62	1,263
1976	21	61	43	103	1,607
1977	28	87	59	143	1,251
1978	45	130	88	132	2,169
1979	31	57	54	65	1,243
1980	33	87	67	111	1,417
1981	57	179	123	269	2,949
1982	66	173	126	464	2,820
1983	84	247	157	717	5,135
1984	108	316	195	1,879	16,501
1985	117	333	212	850	7,341
1986	115	368	205	1,317	8,145

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1987	150	560	337	1,808	12,190
1988	169	567	357	2,084	14,638
1989	160	591	369	2,235	13,604
1990	151	507	341	2,093	14,772
1991	159	405	289	1,414	9,786
1992	59	135	108	343	4,530
1993.1	58	120	94	224	1,960
1993.2	39	64	54	114	1,319
1994	64	123	93	302	2,717
1995	70	122	104	159	1,836
1996	58	145	111	301	3,141
1997	64	128	109	277	2,422
1998	56	103	88	168	1,572
1999	47	93	71	194	1,251
2000	61	137	108	282	2,418
2001	70	154	117	354	2,504
2002	89	180	140	429	3,085
2003	102	342	231	1,321	7,590
2004	124	360	243	1,213	7,216
2005	113	338	231	1,506	9,271
2006	107	302	228	679	3,650
2007	112	394	260	953	7,402
2008	150	444	319	1,126	7,383
2009	150	456	328	1,472	7,697
2010	143	505	342	1,660	9,082
2011	146	442	302	1,074	6,857
2012	135	508	328	1,273	8,282
2013	123	400	274	965	6,470
2014	130	378	267	1,262	7,627
2015	113	356	253	1,563	6,243
2016	113	363	257	992	5,961
2017	127	396	276	1,472	8,274
2018	100	294	200	1,172	5,262
2019	96	289	203	725	4,784
2020	116	326	223	815	5,172
2021	66	211	142	469	3,401
10-year avg.	**112**	**352**	**242**	**1,071**	**6,148**
20-year avg.	**118**	**364**	**252**	**1,107**	**6,535**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 19. Time series of commercial fishing reports for uhu (*Scaridae* spp.; parrotfish) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	33	273	105	301	6,653
1966	20	235	94	336	6,460
1967	29	248	112	678	8,428
1968	31	199	104	531	4,572
1969	44	372	153	733	7,710
1970	43	347	163	1,320	9,012
1971	57	348	184	640	7,044
1972	45	255	126	400	3,284
1973	45	253	141	500	4,405
1974	60	263	151	541	5,215
1975	39	243	123	295	3,624
1976	59	272	159	406	9,633
1977	76	393	228	427	6,418
1978	124	598	369	955	19,775
1979	125	437	364	1,004	19,718
1980	119	586	333	1,425	22,509
1981	116	740	344	1,519	21,487
1982	96	633	316	1,099	16,782
1983	107	568	293	3,103	25,782
1984	117	620	315	3,423	27,694
1985	110	763	337	1,428	27,697
1986	124	823	359	1,991	35,171
1987	134	853	388	3,289	41,016
1988	122	865	356	3,104	44,689
1989	114	759	313	2,044	31,511
1990	75	586	250	2,284	25,999
1991	117	734	358	2,676	26,708
1992	103	964	364	5,388	36,697
1993.1	103	908	336	3,034	26,499
1993.2	79	518	206	2,290	19,382
1994	124	967	413	4,767	39,803
1995	139	1,165	479	2,817	42,036
1996	143	1,047	494	2,579	36,189
1997	131	995	451	2,731	35,968
1998	132	995	446	3,635	35,805
1999	120	952	442	4,511	35,060
2000	116	785	375	3,141	28,510
2001	113	800	386	3,819	21,786

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2002	111	885	391	4,324	31,324
2003	92	822	315	8,377	35,483
2004	84	854	340	7,762	33,279
2005	88	737	296	7,967	32,583
2006	80	637	272	7,684	31,698
2007	84	867	353	11,090	40,398
2008	90	954	371	11,445	44,937
2009	118	1,161	459	11,556	50,884
2010	108	1,441	450	17,484	71,028
2011	96	1,190	409	17,687	72,347
2012	117	1,399	462	20,301	84,442
2013	96	1,197	399	17,689	76,813
2014	89	934	348	14,190	69,929
2015	75	642	274	7,461	33,661
2016	66	585	254	6,411	26,204
2017	70	668	276	7,939	32,572
2018	57	746	247	10,487	51,615
2019	62	605	209	9,834	45,606
2020	50	549	188	9,487	43,893
2021	44	418	149	5,083	24,090
10-year avg.	**73**	**774**	**281**	**10,888**	**48,883**
20-year avg.	**84**	**865**	**323**	**10,713**	**46,639**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 20. Time series of commercial fishing reports for he‘e (*Octopus cyanea*; day tako) reported by Calendar Year from 2003-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2003	77	666	221	6,128	17,592
2004	62	749	228	5,966	19,228
2005	80	824	262	6,250	19,614
2006	75	959	277	7,134	19,284
2007	77	817	293	6,286	17,318
2008	92	962	333	10,425	29,998
2009	96	1,056	358	10,581	30,908
2010	115	1,176	392	11,216	34,089
2011	95	996	351	10,735	30,142
2012	92	1,191	405	11,969	34,602
2013	88	1,155	413	13,436	39,206
2014	86	866	311	10,422	33,637
2015	68	737	243	10,607	32,713
2016	56	588	184	8,158	22,938

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2017	60	523	205	7,265	19,895
2018	57	431	198	4,512	12,642
2019	49	367	167	4,070	11,082
2020	41	206	122	1,521	4,360
10-year avg.	**38**	**205**	**101**	**2,299**	**6,922**
20-year avg.	**64**	**627**	**235**	**7,426**	**21,800**

Table 21. Time series of commercial fishing reports for kala (*Naso* spp.; bluespine unicornfish, short-nosed unicornfish, whitemargin unicornfish) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	27	251	93	823	30,278
1966	20	220	60	174	26,115
1967	27	168	68	398	35,453
1968	24	160	57	423	23,886
1969	31	182	83	560	32,020
1970	40	226	108	1,114	23,954
1971	45	223	118	1,036	19,925
1972	52	189	106	703	16,421
1973	43	151	99	1,084	17,508
1974	57	166	122	1,034	20,793
1975	72	248	159	905	17,997
1976	73	233	167	1,236	13,697
1977	94	369	244	1,374	18,960
1978	103	279	226	1,143	21,775
1979	95	240	222	805	14,430
1980	90	223	174	807	10,397
1981	80	334	166	1,697	11,990
1982	86	345	179	1,515	13,525
1983	89	335	195	822	14,791
1984	92	257	171	492	11,560
1985	98	348	215	1,004	8,890
1986	98	226	159	926	14,647
1987	86	260	177	1,217	14,644
1988	95	298	184	2,348	13,050
1989	102	345	216	864	8,912
1990	49	218	118	527	3,191
1991	91	359	194	809	8,736
1992	74	295	172	477	6,892
1993.1	73	347	183	724	7,805

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1993.2	50	174	90	325	4,445
1994	84	419	229	1,332	12,945
1995	87	478	250	780	17,679
1996	102	496	270	859	15,105
1997	91	500	268	940	12,929
1998	97	497	276	1,413	15,244
1999	90	477	266	1,384	16,439
2000	74	455	223	1,912	18,115
2001	84	426	238	1,832	24,427
2002	77	516	253	2,993	20,243
2003	67	449	187	4,169	21,218
2004	59	419	177	5,074	21,855
2005	51	330	140	5,447	22,502
2006	48	329	141	5,392	21,693
2007	52	310	163	3,712	13,629
2008	55	372	169	5,022	20,227
2009	85	437	245	4,941	24,919
2010	66	578	253	8,182	33,955
2011	68	514	216	7,303	29,724
2012	69	688	247	8,559	42,464
2013	66	534	241	6,946	32,580
2014	61	480	198	6,624	30,216
2015	48	363	174	4,717	21,917
2016	41	305	140	4,056	12,665
2017	42	301	152	5,433	19,620
2018	33	208	117	2,731	10,078
2019	32	154	100	2,323	8,843
2020	31	182	110	3,149	11,302
2021	23	123	74	3,345	12,486
10-year avg.	**45**	**334**	**155**	**4,788**	**20,217**
20-year avg.	**54**	**380**	**175**	**5,006**	**21,607**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 22. Time series of commercial fishing reports for nenue (*Kyphosus* spp.; chubs) from reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	20	113	70	382	6,209
1966	18	97	61	299	6,908
1967	33	132	83	472	11,908
1968	24	70	49	266	2,428
1969	41	111	82	777	8,611

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1970	48	120	89	558	3,088
1971	57	163	118	84	4,187
1972	53	146	105	322	4,621
1973	61	131	106	332	4,746
1974	58	175	122	658	10,553
1975	83	208	146	1,110	16,750
1976	78	227	151	971	10,433
1977	104	288	215	1,692	9,426
1978	119	292	239	1,499	10,535
1979	107	247	223	1,294	8,780
1980	84	258	177	810	13,104
1981	92	342	199	963	10,788
1982	80	428	238	2,980	19,782
1983	96	301	207	1,504	8,181
1984	116	360	241	2,223	11,282
1985	116	423	274	1,619	8,957
1986	124	412	270	2,188	10,980
1987	122	583	307	2,689	17,672
1988	109	542	278	2,483	18,445
1989	94	433	231	2,024	8,430
1990	70	310	173	1,409	6,046
1991	100	413	224	2,349	11,122
1992	80	408	221	812	15,459
1993.1	94	402	222	1,186	7,378
1993.2	57	202	107	734	3,531
1994	98	445	241	1,505	10,753
1995	100	423	259	1,293	10,872
1996	106	525	270	2,206	11,952
1997	102	484	262	2,310	7,515
1998	97	451	243	2,824	15,503
1999	92	474	260	3,492	16,042
2000	83	400	208	1,844	9,704
2001	73	358	209	1,740	11,750
2002	84	376	223	2,018	22,627
2003	64	262	159	5,084	19,476
2004	68	312	194	5,809	19,310
2005	54	252	150	8,867	19,623
2006	59	245	150	12,651	35,621
2007	64	286	173	10,902	26,758
2008	77	334	201	8,287	21,621

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2009	104	469	279	5,735	14,583
2010	79	450	240	14,410	31,690
2011	82	506	220	9,901	27,755
2012	91	571	239	7,442	31,238
2013	78	425	225	5,685	27,473
2014	84	418	221	4,664	16,638
2015	56	279	157	3,697	17,443
2016	55	258	153	3,290	10,465
2017	57	256	147	2,677	6,901
2018	44	267	129	5,135	9,677
2019	37	216	105	4,274	10,199
2020	32	210	107	3,666	9,346
2021	26	136	85	2,928	8,468
10-year avg.	**56**	**304**	**157**	**4,346**	**14,785**
20-year avg.	**65**	**326**	**178**	**6,356**	**19,346**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 23. Time series of commercial fishing reports for manini (*Acanthurus triostegus*; convict tang) reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	40	440	179	9,811	9,244
1966	34	316	158	11,170	7,391
1967	50	293	172	11,480	8,767
1968	41	279	171	11,559	7,046
1969	53	391	188	19,598	12,401
1970	52	372	178	15,977	9,990
1971	79	387	209	11,860	8,527
1972	63	326	182	8,337	7,360
1973	76	424	224	11,859	9,234
1974	89	511	266	11,836	8,682
1975	86	512	246	9,382	9,463
1976	82	483	255	8,714	8,337
1977	103	575	326	6,586	10,236
1978	112	463	352	6,014	9,653
1979	103	437	338	9,687	14,440
1980	86	381	239	4,832	7,121
1981	90	404	251	6,369	15,907
1982	77	463	222	6,405	9,152
1983	86	452	253	2,294	11,091
1984	98	471	266	2,320	9,505

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1985	97	533	275	1,737	9,472
1986	98	549	274	4,226	6,971
1987	94	654	299	5,374	11,042
1988	94	670	319	7,739	9,037
1989	101	705	330	8,126	12,637
1990	68	542	224	6,364	6,977
1991	93	641	294	7,595	7,667
1992	85	649	255	5,788	9,575
1993.1	89	733	265	7,803	9,286
1993.2	66	305	139	5,258	8,193
1994	98	778	303	15,968	12,923
1995	106	777	309	11,216	14,961
1996	113	1,007	367	18,570	18,331
1997	98	896	341	16,397	15,032
1998	105	754	325	19,039	13,317
1999	107	704	310	16,454	14,612
2000	86	563	247	12,943	12,152
2001	78	543	233	10,555	11,919
2002	79	591	255	18,103	15,912
2003	61	560	213	38,573	20,008
2004	61	614	230	20,445	10,057
2005	63	481	220	27,947	12,312
2006	69	539	207	20,059	9,109
2007	66	715	258	26,578	11,398
2008	70	623	272	20,623	11,602
2009	79	718	300	25,386	12,793
2010	85	895	332	31,005	17,496
2011	76	872	296	33,450	17,746
2012	79	768	297	23,949	14,039
2013	66	744	280	28,089	15,896
2014	59	593	247	25,475	11,609
2015	65	406	205	14,261	9,152
2016	47	445	187	18,675	8,957
2017	47	406	181	23,423	10,441
2018	42	469	174	29,252	13,777
2019	40	355	149	18,498	8,725
2020	34	333	139	26,565	12,779
2021	32	306	112	20,889	8,663
10-year avg.	**51**	**483**	**197**	**22,908**	**11,404**
20-year avg.	**61**	**572**	**228**	**24,562**	**12,624**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

Table 24. Time series of commercial fishing reports for ta‘ape (*Lutjanus kasmira*; bluestripe snapper) reported by Fiscal Year from 1970-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1970	5	26	11	-	534
1971	30	109	57	29	1,723
1972	48	198	100	332	2,591
1973	60	249	135	862	3,749
1974	77	322	178	1,304	7,829
1975	88	353	211	1,085	9,353
1976	142	527	320	8,326	28,405
1977	201	801	436	6,853	28,541
1978	289	1,089	741	14,524	50,933
1979	320	972	845	25,672	58,175
1980	331	1,153	762	17,912	56,056
1981	299	1,448	756	20,295	80,498
1982	298	1,451	782	20,871	71,101
1983	308	1,508	799	11,078	69,225
1984	335	1,485	798	13,861	43,747
1985	364	1,748	872	12,844	50,787
1986	410	1,944	1,012	16,189	52,328
1987	372	1,629	948	13,519	55,084
1988	417	1,908	1,037	16,970	50,894
1989	389	1,629	957	15,746	36,211
1990	400	1,635	954	17,099	43,888
1991	426	1,768	1,048	17,041	62,487
1992	343	1,865	949	19,302	74,105
1993.1	330	1,739	875	19,735	62,315
1993.2	249	991	507	11,260	30,092
1994	338	1,690	882	16,459	59,773
1995	365	1,783	951	14,943	71,781
1996	352	1,538	904	14,415	44,195
1997	365	1,983	979	23,281	85,497
1998	365	1,754	933	20,894	74,851
1999	297	1,821	841	31,734	70,073
2000	280	1,926	817	27,267	55,041
2001	240	1,593	666	17,328	47,550
2002	234	1,202	635	14,403	41,147
2003	211	1,068	541	28,194	42,130
2004	210	1,149	554	62,451	45,718

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
2005	176	1,033	487	45,580	39,479
2006	171	1,003	461	28,317	29,438
2007	187	1,130	529	35,662	30,281
2008	247	1,220	619	43,786	40,000
2009	274	1,392	717	49,927	38,390
2010	270	1,518	767	57,553	43,538
2011	265	1,369	693	56,221	41,261
2012	297	1,394	800	37,849	33,003
2013	269	1,394	734	38,888	33,451
2014	261	1,233	658	35,159	30,271
2015	227	1,074	582	31,077	25,823
2016	221	1,107	590	39,258	33,902
2017	241	1,247	669	60,647	37,200
2018	199	871	499	43,388	28,835
2019	178	831	465	44,856	29,583
2020	178	761	435	72,749	37,828
2021	142	702	370	62,198	30,937
10-year avg.	**221**	**1,061**	**580**	**46,607**	**32,083**
20-year avg.	**223**	**1,135**	**590**	**44,408**	**35,611**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.3.4 Bycatch Summary

Bycatch for non-MUS has been decreasing overall since a peak in 2007. This trend in non-MUS bycatch can be attributed almost entirely to the akule and ‘opelu fisheries, which since 2002 typically make up approximately 69% of all non-MUS caught each year. High reported releases by akule and ‘opelu fishers using net gear types, in particular pelagic purse seine, seine, and gill nets, have a disproportionately large influence on the total released of non-MUS. Because akule and ‘opelu are caught in large numbers with these gears, a single release event can result in up to 90,000 pieces reported as released. Fishers will occasionally do so to avoid flooding the market and/or release fish they cannot handle. While annual releases of akule and ‘opelu have ranged between 0.04% to 20.3% of catch, total bycatch rates of other non-MUS are more stable, ranging between 2.1% and 9.0%. Non-MUS bycatch was below average in 2021 largely due to proportionally low releases of akule and ‘opelu.

Table 25. Time series of commercial fishing bycatch of non-MUS reported by Calendar Year from 2002-2021

Year	No. Lic.	Trips	No. Reports	No. Retained	No. Released	Percent Bycatch
2002	997	12,060	3,897	794,750	44,156	5.26
2003	888	11,718	3,608	1,352,457	100,021	6.89
2004	875	11,865	3,539	1,249,356	57,736	4.42

Year	No. Lic.	Trips	No. Reports	No. Retained	No. Released	Percent Bycatch
2005	862	10,081	3,155	1,068,289	167,912	13.58
2006	761	9,446	2,891	1,193,618	133,748	10.08
2007	824	10,792	3,262	2,217,897	369,774	14.29
2008	963	11,463	3,662	1,877,246	237,940	11.25
2009	1,116	13,789	4,377	1,788,814	230,382	11.41
2010	1,102	14,387	4,538	1,703,320	135,766	7.38
2011	1,028	12,630	4,084	1,736,035	99,615	5.43
2012	1,032	12,592	4,220	1,511,879	17,225	1.13
2013	980	12,225	4,077	1,503,004	43,129	2.79
2014	951	10,901	3,848	1,559,658	32,191	2.02
2015	915	10,127	3,641	1,433,792	21,683	1.49
2016	792	8,879	3,209	1,502,188	97,984	6.12
2017	801	8,717	3,259	1,417,473	21,228	1.48
2018	721	7,522	2,832	1,303,903	28,208	2.12
2019	678	7,057	2,737	1,197,640	22,769	1.87
2020	650	6,238	2,492	1,235,894	24,969	1.98
2021	600	5,554	2,174	1,112,220	21,814	1.92
10-year avg.	**812**	**8,981**	**3,249**	**1,377,765**	**33,120**	**2.29**
20-year avg.	**877**	**10,402**	**3,475**	**1,437,972**	**95,413**	**5.64**

1.4 CRUSTACEAN

1.4.1 Fishery Descriptions

The crustacean management unit species (CMUS) include two species of deepwater shrimp (*Heterocarpus laevigatus* and *H. ensifer*) and the Kona crab (*Ranina ranina*). Despite being combined into one MUS, these two fisheries are extremely different. Kona crab are found across the MHI in habitat comprised soft sandy bottoms in which they spend nearly their entire lives burrowed. Though found at depths as great as 200 m, they are commonly fished at shallower depths allowing gear to be set and retrieved by hand. Kona crab have long been considered a delicacy in Hawaii eaten both cooked and raw. DAR records of commercial Kona crab catch date back to the mid-1940's. In 1972, commercial landings peaked at approximately 72,000 lbs.

Conversely, the deepwater shrimp fishery is relatively new to Hawaii, with landings first appearing in commercial records in the early 1980s. As their name implies, these species are often fished at depths in excess of 300 m requiring automatic haulers to retrieve gear. Deepwater shrimp are most commonly known for their use in Japanese restaurants where they are often sold as amaebi. Today, with a lack of an export market and limited local demand, the deepwater shrimp fishery in the MHI remains small in comparison to its previous size.

1.4.2 Dashboard Statistics

The collection of commercial crustacean fishing reports comes from two sources: paper reports received by mail, fax, or PDF copy via e-mail; and reports filed online through the OFR. The crustacean landings are reported by commercial fishers on the Monthly Fishing Report, the Net, Trap, Dive Activity Report, or the MHI Deep-7 Bottomfish Fishing Trip Report.

Similar to the Deep-7 Bottomfish, the time series format for the crustacean fishery begins with an arrangement by the State fiscal year period (July – June) until June 1993 before being reported by calendar year. Refer to data processing procedures documented in the Deep-7 BMUS section (Section 1.1.2) for more information on paper fishing reports and fishing reports filed online. Database assistants and data monitoring associates will enter the paper Monthly Fishing Report information within four weeks, and the Net, Trap, Dive Activity Report and the MHI Deep-7 Bottomfish Fishing Trip Report within two business days.

1.4.2.1 Historical Summary

CMUS catch, number of licenses, and number of trips in 2021 were all below 10- and 20-year averages. Both the deepwater shrimp and Kona crab fisheries have seen substantial changes in both the short- and long-term effort and landings due to a variety of factors including the demise of the deepwater shrimp export fishery, highliner loss, and new Kona crab restrictions.

Table 26. Annual fishing parameters for 2021 in the MHI crustacean fishery compared with short-term (10-year) and long-term (20-year) averages

Fishery	Parameters	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Crustacean	No. License	20	↓28.6%	↓45.9%
	Trips	117	↓49.6%	↓51.9%
	No. Caught	4,418	↓94.8%	↓91.7%
	Catch (lb)	8,720 lb	↓58.7%	↓65.9%

1.4.2.2 Species Summary

Shrimp trap parameters could not be reported due to fewer than three distinct CML holders reporting catch. The number of licenses and trips using the Kona crab net gear type in 2021 were below both short- and long-term averages. Pounds caught using Kona crab nets was also below short- and long-term averages, but to a lesser degree than the 2021 decrease in trips. As a result, CPUE for the Kona crab net gear type in 2021 increased in comparison to short- and long-term averages. CMUS catch using All Other Gears is typically comprised entirely of Kona Crab caught incidentally in other crab gears. Catch and effort trends from All Other Gears fluctuate between years due to the low catch and effort and incidental nature.

Table 27. Annual fishing parameters for 2021 in the MHI crustacean fishery compared with short-term (10-year) and long-term (20-year) averages

Methods	Fishery Indicator	2021 Value	2021 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Shrimp Trap	*H. laevigatus*	n.d.	-	-
	H. ensifer	n.d.	-	-
	No. Lic.	n.d.	-	-
	No. Trips	n.d.	-	-
	Catch	n.d.	-	-
	CPUE	n.d.	-	-
Kona Crab Net	Kona crab	3,822 lb	↓4.97%	↓47.0%
	No. Lic.	17	↓26.1%	↓48.5%
	No. Trips	45	↓26.2%	↓61.9%
	Catch	3,822 lb	↓4.97%	↓47.0%
	CPUE	84.93 lb/trip	↑32.8%	↑37.1%
All Other Gears	No. Lic.	3	↑50.0%	0.00%
	No. Trips	24	↑71.4%	↑14.3%
	Catch	124	↑42.5%	↓23.5%
	CPUE	5.17 lb/trip	↓26.4%	↓71.4%

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.

1.4.3 Time Series Statistics

CMUS catch (weight) has been highly variable since 1965 and is currently in a state of decline. Catch in terms of pieces is likely unreliable for CMUS due to limited deepwater shrimp count data (pieces often unreported). CMUS fishery licenses and reports both peaked in 1998 and have been declining steadily since. Like catch, effort has been variable over the time series with multiple distinct peaks in annual number of trips occurring since 1965. It is again important to note that the two fisheries included in CMUS are very different in both their operation and catch trends. Because of those differences, care must be taken when using combined CMUS data to make inferences about the state of the individual contributing fisheries.

1.4.3.1 Commercial Fishing Parameters

Table 28. Time series of commercial fishermen reports for the CMUS fishery reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1965	26	171	71	4,238	11,421
1966	22	179	67	3,604	10,033
1967	30	185	82	3,071	17,444
1968	25	167	71	1,764	26,419
1969	29	233	84	3,109	35,955
1970	30	197	78	2,544	35,042
1971	40	254	111	4,162	43,576
1972	41	260	102	3,042	69,331
1973	32	231	97	2,111	62,515
1974	49	211	112	7,562	40,552
1975	59	241	127	5,076	24,616
1976	59	234	136	8,568	26,577
1977	54	233	114	4,144	23,153
1978	61	243	159	5,224	31,675
1979	52	202	128	5,817	28,711
1980	42	108	67	1,920	10,390
1981	50	157	103	6,717	17,858
1982	52	178	108	2,386	8,701
1983	55	180	107	4,204	13,130
1984	76	386	157	6,303	214,792
1985	80	460	190	6,052	82,741
1986	82	312	176	4,196	27,575
1987	76	239	133	3,831	23,876
1988	53	242	101	2,906	30,684
1989	37	148	63	916	60,726
1990	44	242	84	2,624	361,914
1991	47	187	87	1,620	89,383

Year	No. License	Trips	No. Reports	No. Caught	Catch (lb)
1992	73	342	133	7,550	38,552
1993.1	70	398	149	4,580	61,525
1993.2	52	187	80	3,047	31,995
1994	74	340	165	3,114	105,179
1995	88	467	200	4,992	98,478
1996	92	401	180	5,291	62,662
1997	90	346	169	8,119	50,913
1998	102	438	207	7,966	213,067
1999	86	298	170	5,810	52,506
2000	65	199	113	4,075	14,970
2001	64	243	130	3,771	20,209
2002	66	248	134	6,593	17,032
2003	53	217	102	10,082	17,632
2004	51	204	90	7,441	13,469
2005	51	381	106	8,240	124,900
2006	38	203	77	5,941	49,666
2007	34	238	75	26,487	13,469
2008	38	302	88	56,257	21,571
2009	41	237	98	15,960	10,645
2010	48	243	96	15,377	13,481
2011	51	272	114	55,352	19,076
2012	40	272	97	115,257	20,106
2013	43	310	101	105,954	26,807
2014	34	398	94	372,676	50,808
2015	32	271	86	150,530	31,693
2016	22	161	53	30,034	17,961
2017	22	142	49	10,207	8,761
2018	25	194	56	33,956	14,551
2019	26	282	67	23,079	18,429
2020	14	168	39	4,810	13,256
2021	20	117	46	4,418	8,720
10-year avg.	**28**	**232**	**69**	**85,092**	**21,109**
20-year avg.	**37**	**243**	**83**	**52,933**	**25,602**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.4.4 Preferred Targets by Gear Type

1.4.4.1 Shrimp Trap

The shrimp trap gear code was established in 1986. Prior to then, all trap activities were reported under “miscellaneous traps.” Of the two species caught, *H. laevigatus* is preferred over *H. ensifer* due to their larger size and superior food quality. Deepwater shrimp catch has pulsed multiple times since the early 1980s, resulting from a small number of large mainland-based vessels periodically entering the fishery primarily for the purpose of export to out of State markets. Fishing by these mainland-based vessels has not occurred since 2006, notably reducing catch. Today, the remaining Hawaii-based deepwater shrimp fishery supplies a limited amount of in-state demand and in recent years is limited to fewer than three reporting license holders.

Despite the potential for high catch, the deepwater shrimp trap fishery is characterized by low participation even in years when mainland-based vessels were active. Peak CMLs active in the shrimp trap fishery occurred in 2013 with ten fishers reporting. Since the peak, participation has declined to three or fewer fishers per year. Catch (weight) has also declined primarily because of the loss the mainland-based vessels and to a lesser extent a few Hawaii-based highliners. Catch and participation for the shrimp trap gear type in 2021 could not be presented in this report to due to fewer than three licensed fishers reporting during the year.

Table 29. DAR MHI annual crustacean catch summary by species for shrimp traps reported by Fiscal Year from 1987-1993 and by Calendar Year from 1994-2021

Year	***Heterocarpus laevigatus***		***Heterocarpus ensifer***	
	No. License	**Catch (lb)**	**No. License**	**Catch (lb)**
1987	3	1,796	n.d.	n.d.
1988	n.d.	n.d.	3	1,568
1989	n.d.	n.d.	n.d.	n.d.
1990	5	341,780	n.d.	n.d.
1991	n.d.	n.d.	-	-
1992	n.d.	n.d.	-	-
1993.1	3	35,631	-	-
1993.2	3	15,627	n.d.	n.d.
1994	5	82,243	n.d.	n.d.
1995	4	66,493	n.d.	n.d.
1996	8	34,588	n.d.	n.d.
1997	6	21,697	n.d.	n.d.
1998	7	180,391	3	1,521
1999	5	33,585	n.d.	n.d.
2000	n.d.	n.d.	n.d.	n.d.
2001	4	9,225	n.d.	n.d.
2002	3	3,779	n.d.	n.d.
2003	3	5,166	n.d.	n.d.
2004	n.d.	n.d.	-	-
2005	5	109,660	n.d.	n.d.
2006	n.d.	n.d.	n.d.	n.d.
2007	n.d.	n.d.	n.d.	n.d.
2008	n.d.	n.d.	n.d.	n.d.
2009	n.d.	n.d.	n.d.	n.d.

Year	***Heterocarpus laevigatus***		***Heterocarpus ensifer***	
	No. License	**Catch (lb)**	**No. License**	**Catch (lb)**
2010	n.d.	n.d.	n.d.	n.d.
2011	4	6,103	n.d.	n.d.
2012	5	11,750	n.d.	n.d.
2013	10	18,977	4	406
2014	9	48,050	4	657
2015	6	28,766	n.d.	n.d.
2016	5	17,158	n.d.	n.d.
2017	3	5,964	n.d.	n.d.
2018	3	11,588	n.d.	n.d.
2019	3	12,630	n.d.	n.d.
2020	n.d.	n.d.	n.d.	n.d.
2021	n.d.	n.d.	n.d.	n.d.
10-year avg.	**5**	**16,864**	**2**	**136**
20-year avg.	**4**	**17,430**	**2**	**835**

"-" = no available data; "n.d." = non-disclosure due to data confidentiality.
1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.4.4.2 Kona Crab Net

Also referred to as loop nets, Kona crab nets are specifically designed to capture the Kona crab. They are characterized by a single or double layer of thin taught cotton or nylon mesh over a metal hoop. Kona crab are caught in the net when their joints become entangled in the thin mesh. The nets are baited with fish bait and clipped at set intervals along a weighted main line stretched along the sandy bottom and market by a buoy at one or both of its terminal ends.

The MHI Kona crab fishery can historically be split into two distinct parts: the inshore fishery occurring in State waters, and the Penguin Bank fishery. The Penguin Bank fishery emerged in the early 1960s and peaked in 1972 when it contributed approximately 90% of catch. Following a second minor peak in 1991, the Penguin Bank fishery steadily declined in catch and discontinued in 2016. The inshore fishery peaked in 1995 and has been in steady decline since.

Effort and landings for the entire MHI Kona Crab fishery have been in a state of overall decline since the late 1990s. The downward trend in catch is due in part to overall declining fishery participation and progressively decreasing activity and the eventual loss of the prominent highliners. Additionally, a challenge to Kona crab fishing is the suite of regulations currently in place including size (4" minimum carapace), sex (no-take of females), seasonal (May-August closed season), and gear-type (no spearing) restrictions. Though a previous stock assessment indicated that the population may be at risk from fishing, the 2018 stock assessment has deemed the MHI population not overfished or experiencing overfishing. As a result, DAR is currently taking steps to allow the take of female Kona crab, which should provide fishers with improved opportunities for retention. It remains unclear what future interest in the fishery will be, though it seems likely that the removal of the no-take of females will result in some increased effort and new intrants. However, without the emergence of new dedicated highliners and return of the Penguin Bank fishery, the fishery may not return to previous levels of catch.

Table 30. DAR MHI annual crustacean catch summary for loop net catching Kona crab reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	No. License	Catch (lb)
1965	25	11,378
1966	21	10,029
1967	30	17,444
1968	25	26,419
1969	28	35,939
1970	29	35,033
1971	38	42,977
1972	40	69,328
1973	32	62,455
1974	49	39,121
1975	58	23,996
1976	50	23,195
1977	33	15,966
1978	60	28,582
1979	51	24,674
1980	39	8,162
1981	47	12,102
1982	48	8,291
1983	48	9,009
1984	58	12,944
1985	71	20,846
1986	80	27,200
1987	62	16,310
1988	47	12,475
1989	32	11,790
1990	32	16,118
1991	44	22,789
1992	71	34,291
1993.1	66	25,305
1993.2	50	15,464
1994	69	19,472
1995	84	27,741
1996	83	27,603
1997	82	27,931
1998	91	30,639
1999	81	18,698

Year	No. License	Catch (lb)
2000	62	14,143
2001	59	10,763
2002	63	12,830
2003	49	11,841
2004	48	12,164
2005	46	9,937
2006	35	6,749
2007	31	9,773
2008	36	10,940
2009	41	9,097
2010	46	9,913
2011	46	10,876
2012	35	7,980
2013	33	7,330
2014	24	2,029
2015	26	2,902
2016	16	745
2017	19	2,753
2018	20	2,769
2019	24	5,688
2020	12	4,201
2021	17	3,822
10-year avg.	**23**	**4,022**
20-year avg.	**33**	**7,217**

1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.4.5 Catch Parameters by Gear

Shrimp trap CPUE over time has, like catch, spiked periodically as a small number of mainland-based vessels returned to Hawaii to catch deepwater shrimp. In years in which those vessels were active, CPUE saw a marked increase due to the high number of gears that the larger and more well-equipped mainland vessels could handle. The 1984 peak in CMUS CPUE using "All Other Gear Types" is due to the lack of a specific shrimp trap gear code offered at that time. Deepwater shrimp fishers prior to 1986 used the "Miscellaneous Trap" gear code in lieu of a dedicated shrimp trap code. In 2021 catch parameters for the deepwater shrimp trap fishery could not be reported due to fewer than three participants.

Kona crab net CPUE spiked in the early 1970s. Rising CPUE during that time was the result of the developing Penguin Bank fishery, where Kona crab are more abundant and larger in size than many inshore fishing areas. Over time, highliner activity decreased and the fishery progressively moved to occurring predominantly in State waters. As a result, CPUE declined. The introduction of regulations, especially the 2006 ban on the take of females also likely played a role in the persistently low CPUE in comparison to historic levels.

Table 31. Time series of crustacean CPUE (lb/trip) in the MHI reported by Fiscal Year from 1965-1993 and by Calendar Year from 1994-2021

Year	Shrimp Trap				Kona Crab Net (Loop)				All Other Gear Types			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
1965	-	-	-	-	25	169	11,378	67	n.d.	n.d.	n.d.	n.d.
1966	-	-	-	-	21	178	10,029	56	n.d.	n.d.	n.d.	n.d.
1967	-	-	-	-	30	185	17,444	94	-	-	-	-
1968	-	-	-	-	25	167	26,419	158	-	-	-	-
1969	-	-	-	-	28	232	35,939	155	n.d.	n.d.	n.d.	n.d.
1970	-	-	-	-	29	195	35,033	180	n.d.	n.d.	n.d.	n.d.
1971	-	-	-	-	38	241	42,977	178	n.d.	n.d.	n.d.	n.d.
1972	-	-	-	-	40	259	69,328	268	n.d.	n.d.	n.d.	n.d.
1973	-	-	-	-	32	230	62,455	272	n.d.	n.d.	n.d.	n.d.
1974	-	-	-	-	49	199	39,121	197	3	12	1,431	119
1975	-	-	-	-	58	233	23,996	103	n.d.	n.d.	n.d.	n.d.
1976	-	-	-	-	50	203	23,195	114	20	31	3,382	109
1977	-	-	-	-	33	133	15,966	120	34	100	7,187	72
1978	-	-	-	-	60	227	28,582	126	n.d.	n.d.	n.d.	n.d.
1979	-	-	-	-	51	188	24,674	131	3	14	4,037	288
1980	-	-	-	-	39	100	8,162	82	6	8	2,228	279
1981	-	-	-	-	47	143	12,102	85	8	14	5,756	411
1982	-	-	-	-	48	163	8,291	51	8	15	410	27
1983	-	-	-	-	48	146	9,009	62	9	34	4,121	121
1984	-	-	-	-	58	179	12,944	72	29	207	201,848	975
1985	-	-	-	-	71	309	20,846	67	18	151	61,895	410
1986	-	-	-	-	80	302	27,200	90	9	10	375	38
1987	4	22	1,831	83	62	158	16,310	103	17	59	5,735	97
1988	3	44	12,934	294	47	179	12,475	70	6	19	5,275	278

Year	Shrimp Trap				Kona Crab Net (Loop)				All Other Gear Types			
	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE	No. Lic.	Trips	Catch (lb)	CPUE
1989	n.d.	n.d.	n.d.	n.d.	32	134	11,790	88	4	8	1,326	166
1990	5	87	343,102	3,944	32	130	16,118	124	14	30	2,694	90
1991	n.d.	n.d.	n.d.	n.d.	44	161	22,789	142	6	11	852	77
1992	n.d.	n.d.	n.d.	n.d.	71	316	34,291	109	4	21	2,363	113
1993.1	3	86	35,631	414	66	309	25,305	82	n.d.	n.d.	n.d.	n.d.
1993.2	3	36	16,531	459	50	151	15,464	102	-	-	-	-
1994	5	86	85,657	996	69	253	19,472	77	n.d.	n.d.	n.d.	n.d.
1995	4	140	70,737	505	84	327	27,741	85	-	-	-	-
1996	8	114	34,973	307	83	283	27,603	98	3	4	86	22
1997	6	51	22,792	447	82	288	27,931	97	3	7	190	27
1998	7	129	181,912	1,410	91	299	30,639	102	4	10	516	52
1999	5	75	33,644	449	81	221	18,698	85	n.d.	n.d.	n.d.	n.d.
2000	n.d.	n.d.	n.d.	n.d.	62	152	14,143	93	n.d.	n.d.	n.d.	n.d.
2001	4	81	9,313	115	59	158	10,763	68	3	4	133	33
2002	3	50	3,989	80	63	196	12,830	65	n.d.	n.d.	n.d.	n.d.
2003	3	56	5,420	97	49	158	11,841	75	3	3	370	123
2004	n.d.	n.d.	n.d.	n.d.	48	167	12,164	73	3	30	133	4
2005	5	178	114,789	645	46	161	9,937	62	n.d.	n.d.	n.d.	n.d.
2006	n.d.	n.d.	n.d.	n.d.	35	128	6,749	53	3	26	172	7
2007	n.d.	n.d.	n.d.	n.d.	31	188	9,773	52	4	13	142	11
2008	n.d.	n.d.	n.d.	n.d.	36	201	10,940	54	4	42	456	11
2009	n.d.	n.d.	n.d.	n.d.	41	191	9,097	48	3	38	325	9
2010	n.d.	n.d.	n.d.	n.d.	46	178	9,913	56	4	45	282	6
2011	4	69	8,098	117	46	172	10,876	63	5	39	103	3
2012	5	143	11,894	83	35	121	7,980	66	3	8	232	29
2013	10	205	19,383	95	33	83	7,330	88	n.d.	n.d.	n.d.	n.d.
2014	9	323	48,707	151	24	59	2,029	34	3	16	72	5

Year	Shrimp Trap				Kona Crab Net (Loop)				All Other Gear Types			
	No. Lic.	**Trips**	**Catch (lb)**	**CPUE**	**No. Lic.**	**Trips**	**Catch (lb)**	**CPUE**	**No. Lic.**	**Trips**	**Catch (lb)**	**CPUE**
2015	6	200	28,775	144	26	62	2,902	47	n.d.	n.d.	n.d.	n.d.
2016	5	133	17,203	129	16	25	745	30	n.d.	n.d.	n.d.	n.d.
2017	3	80	5,984	75	19	53	2,753	52	n.d.	n.d.	n.d.	n.d.
2018	3	131	11,598	89	20	52	2,769	53	3	12	184	15
2019	3	196	12,692	65	24	71	5,688	80	n.d.	n.d.	n.d.	n.d.
2020	n.d.	n.d.	n.d.	n.d.	12	42	4,201	100	n.d.	n.d.	n.d.	n.d.
2021	n.d.	n.d.	n.d.	n.d.	17	45	3,822	85	3	24	124	5
10-yr avg.	**5**	**157**	**17,000**	**101**	**23**	**61**	**4,022**	**64**	**2**	**14**	**87**	**7**
20-yr avg.	**4**	**106**	**18,223**	**172**	**33**	**118**	**7,217**	**62**	**3**	**21**	**162**	**18**

“-“ = no available data; “n.d.” = non-disclosure due to data confidentiality
1993.1 = Fiscal Year 1993; 1993.2 = July-December of calendar year 1993.

1.4.6 Bycatch Summary

Percent bycatch for the Kona crab fishery is extremely high due to the current suite of regulations in place. MHI Kona crab populations typically (seasonal and place-based differences in sex ration have also been noted) have a near 1:1 male to female sex ratio meaning that at minimum about half the catch would need to be released during an average trip. Considering that undersized males also need to be released, it is easy to see how fishers today struggle to retain catch legally. Reported percent Kona crab bycatch appears to be increasing, with 2021 percent bycatch (87%) being the second highest on record. It is likely though that this is influenced by significant under reporting of releases, especially early in the time series. Percentage of total Kona crab reports with zero releases (highly improbable) have been declining steadily suggesting that fishers are progressively reporting releases more frequently. However, under reporting is still an issue today and may suggest that percent bycatch may be even higher than reflected below.

Non-target species catch using Kona crab nets is extremely limited, and typically comprised almost entirely of the kuahonu crab (*P. sanguinolentus*) which also favors sandy bottoms. Unlike Kona crab, kuahonu crab are not as prone to entanglement in the mesh of Kona crab nets and can often escape capture during retrieval. A relatively high percent bycatch for kuahonu crab is due in part to current regulations including a minimum size and the prohibition of the take of females carrying eggs. In 2021 non-target species catch for the Kona crab loop net fishery could not be reported due to fewer than three reporting licensees.

Percent bycatch for the deepwater shrimp trap fishery is hard to determine from report data since releases can only be reported in pieces, and catch is often only reported in pounds. Seemingly high percent bycatch as seen in 2016 is the result of fishers reporting releases in pieces but neglecting to report at all catch in pieces. It is likely though that target species releases are infrequent since there are no size or sex-based restrictions. Releases of deepwater shrimp in 2021 could not be detailed below due to fewer than three participants in the fishery.

Non-target species catch in shrimp traps is not commonly reported. In many years no non-target catch is reported at all. Once again, non-target catch and releases using deepwater shrimp traps could not be detailed below due to fewer than three participants in the fishery

Table 32. Time series of commercial fishing bycatch of Kona crab and non-target species harvested with loop net, reported by Fishing Year from 2002-2021

	Target Species (Kona Crab)						Non-Target Species (Harvested with Loop Net)					
Year	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**
2002	63	196	119	6,593	195	2.87	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2003	51	161	85	6,044	1,080	15.16	4	6	6	42	-	-
2004	50	197	85	7,441	1,620	17.88	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2005	47	203	84	8,110	1,173	12.64	3	9	6	24	-	-
2006	36	154	70	5,941	3,688	38.30	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2007	32	200	69	9,657	3,422	26.16	3	6	4	43	-	-
2008	38	243	84	12,076	1,376	10.23	3	10	10	64	6	8.57
2009	41	229	97	7,783	2,295	22.77	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2010	48	198	92	8,863	6,511	42.35	3	12	8	27	4	12.90
2011	49	189	105	8,783	7,360	45.59	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2012	36	115	77	8,138	3,716	31.35	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2013	34	97	66	5,122	7,816	60.41	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2014	26	75	53	1,666	5,576	77.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2015	26	71	50	2,185	7,450	77.32	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2016	17	28	26	617	1,917	75.65	-	-	-	-	-	-
2017	19	62	39	2,697	6,947	72.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2018	22	63	40	2,760	12,141	81.48	3	4	4	164	748	82.02
2019	24	86	45	4,654	27,186	85.38	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2020	12	60	25	3,190	24,297	88.39	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2021	18	69	38	2,688	17,764	86.86	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
10-year avg.	**23**	**73**	**46**	**3,372**	**11,481**	**73.59**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
20-year avg.	**34**	**135**	**67**	**5,750**	**7,177**	**48.49**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**

"-"= no available data; "n.d." = non-disclosure due to data confidentiality.

Table 33. Time series of commercial fishing bycatch of deepwater shrimp and non-target species harvested with shrimp traps, reported by Fishing Year from 2002-2021

	Target Species (Deepwater Shrimp)						Non-Target Species (Harvested with Shrimp Traps)					
Year	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**	**No. Lic.**	**Trips**	**No. Reports**	**No. Retained**	**No. Released**	**Percent Bycatch**
2002	3	52	15	-	-	-	-	-	-	-	-	-
2003	3	56	18	4,038	-	-	-	-	-	-	-	-
2004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-
2005	5	178	24	130	4	2.99	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-
2007	3	39	10	16,830	-	-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-
2009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-
2010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2011	4	69	16	46,569	-	-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2012	5	143	21	107,119	100	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2013	10	205	36	100,832	-	-	-	-	-	-	-	-
2014	9	323	41	371,010	34	0.01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2015	6	200	36	148,345	310	0.21	-	-	-	-	-	-
2016	5	133	27	29,417	3,205	9.82	-	-	-	-	-	-
2017	3	80	10	7,510	20	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2018	3	131	16	31,196	-	-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2019	3	196	23	18,425	-	-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-
2021	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
10-year avg.	**5**	**157**	**23**	**81,720**	**367**	**1.04**	**1**	**9**	**3**	**38**	**0**	**0**
20-year avg.	**4**	**106**	**18**	**47,182**	**184**	**0.79**	**1**	**9**	**3**	**263**	**7**	**14.02**

"-"= no available data; "n.d." = non-disclosure due to data confidentiality.

1.5 PRECIOUS CORALS FISHERY

1.5.1 Fishery Descriptions

This species group is comprised of pink/red coral (*Corallium secundum*, *C. regale*, *C. laauense*), gold coral (*Gerardia* spp., *Callogorgia gilberti*, *Narella* spp., *Calyptrophora* spp.), bamboo coral (*Lepidisis olapa*, *Acanella* spp.), and black coral (*Antipathes griggi*, *A. grandis*, *A. ulex*).

Precious corals have long been prized by a wide range of cultures for their use in jewelry making. In 1987 black coral was adopted as the official state "gem" of Hawaii. Throughout the entire time series of commercial reporting, black corals compose almost the entirety of the precious coral harvest. Approximately 93% of all precious coral harvest reported to DAR has occurred in or around the Auau channel. MHI precious coral fisheries are characterized by extremely low participation which peaked at five individuals in 1987 and 1990. In the past eleven years combined, fewer than three individuals have reported harvest of these species.

1.5.2 Dashboard Statistics

Future reports will include data as resources allow (see Section 1.5.3)

1.5.3 Other Statistics

Commercial fishery statistics for recent years are unavailable due to data confidentiality restrictions, as the number of active participants has been fewer than three since the 2011–2012 fishing year. Future reports will include data as resources and reporting confidentiality thresholds allow.

1.6 FEDERAL LOGBOOK DATA

1.6.1 Number of Federal Permit Holders

In Hawaii, the following federal permits are required for fishing in the exclusive economic zone (EEZ) under the Hawaii FEP. Regulations governing fisheries under the Hawaii FEP are in the Code of Federal Regulations (CFR), Title 50, Part 665.

1.6.1.1 Special Coral Reef Ecosystem Permit

Regulations require the special coral reef ecosystem fishing permit for anyone fishing for coral reef ECS in a low-use marine protected area (MPA), fishing for species on the list of Potentially Harvested Coral Reef Taxa or using fishing gear not specifically allowed in the regulations. NMFS will make an exception to this permit requirement for any person issued a permit to fish under any fishery ecosystem plan who incidentally catches Hawaii coral reef ECS while fishing for BMUS, CMUS or crustacean ECS, western Pacific pelagic MUS, precious coral, or seamount groundfish. Regulations require a transshipment permit for any receiving vessel used to land or transship potentially harvested coral reef taxa, or any coral reef ECS caught in a low-use MPA.

1.6.1.2 Main Hawaiian Islands Non-Commercial Bottomfish

Regulations require this permit for any person, including vessel owners, fishing for BMUS or bottomfish ECS in the EEZ around the MHI. If the participant possesses a current State of Hawaii CML, or is a charter fishing customer, he or she is not required to have this permit.

1.6.1.3 Western Pacific Precious Coral

Regulations require this permit for anyone harvesting or landing black, bamboo, pink, red, or gold corals in the EEZ in the western Pacific. The Papahānaumokuākea Marine National Monument prohibits precious coral harvests in the monument (71 FR 51134, August 29, 2006). Regulations governing this fishery are in the CFR, Title 50, Part 665, Subpart F, and Title 50, Part 404 (Papahānaumokuākea Marine National Monument).

1.6.1.4 Western Pacific Crustaceans Permit

Regulations require a permit for the owner of a U.S. fishing vessel used to fish for lobster (now ECS) or deepwater shrimp in the EEZ around American Samoa, Guam, Hawaii, and the Pacific Remote Islands Area (PRIA), and in the EEZ seaward of three nautical miles of the shoreline of the CNMI.

Table 34 provides the number of permits issued to Hawaii FEP fisheries between 2012 and 2021. Data are from the PIRO Sustainable Fisheries Division (SFD) permits program.

Table 34. Number of federal permits in Hawaii FEP fisheries

Year	Special Coral Reef Ecosystem	MHI Non-Commercial Bottomfish	Precious Coral	Crustacean - Shrimp	Crustacean - Lobster
2012	1	18	2	0	0
2013	0	10	1	3	2
2014	0	3	1	7	1
2015	0	2	1	4	2

Year	Special Coral Reef Ecosystem	MHI Non-Commercial Bottomfish	Precious Coral	Crustacean - Shrimp	Crustacean - Lobster
2016	1	0	1	4	1
2017	1	1	1	6	2
2018	1	0	1	4	1
2019	0	2	1	3	1
2020	1	2	0	2	0
2021	1	0	0	3	0

Source: PIRO SFD unpublished data.

1.6.2 Summary of Catch and Effort for FEP Fisheries

The Hawaii Archipelago FEP requires fishermen to obtain a federal permit to fish for certain MUS in federal waters and to report all catch and discards. While NMFS annually issues permits for various FEP fisheries, there is currently limited available data on the level of catch or effort made by federal non-longline permit holders. Determining the level of fishing activity through the required federal logbook reporting for each fishery helps establish the level of non-longline fishing occurring in federal waters to assess whether there is a continued need for active conservation and management measures (e.g., annual catch limits) for these fisheries. For each FEP fishery, the number of federal permits issued since the federal permit and logbook reporting requirements became effective as well as available catch and effort data are presented in Table 35 through Table 37.

1.6.2.1 Precious Coral

There have been less than three permittees for the precious coral fishery in recent years (see Section 1.5.3), so any reports received are confidential.

1.6.2.2 Non-Commercial Bottomfish

Table 35. Summary of available federal logbook data for the non-commercial bottomfish fishery in Hawaii

Year	No. of Federal Bottomfish Permits Issued[1]	No. of Federal Bottomfish Permits Reporting Catch	No. of Trips in MHI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (#)	
				Dee- 7 Bottomfish (MUS) from Sept 1-Aug. 31 the following year	*Non-Deep-7 Bottomfish (MUS & ECS)[2] from Jan. 1 to Dec. 31*	*Deep-7 Bottomfish (MUS) from Sept 1-Aug. 31 the following year*	*Non-Deep-7 Bottomfish (MUS & ECS)[2] from Jan. 1 to Dec. 31*
2008-09	80	4	9	182	32	0	0
2009-10	59	4	11	309	10	0	3
2010-11	22	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2011-12	18	0					

Year	No. of Federal Bottomfish Permits Issued[1]	No. of Federal Bottomfish Permits Reporting Catch	No. of Trips in MHI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (#)	
				Dee- 7 Bottomfish (MUS) from Sept 1-Aug. 31 the following year	*Non-Deep-7 Bottomfish (MUS & ECS)[2] from Jan. 1 to Dec. 31*	*Deep-7 Bottomfish (MUS) from Sept 1-Aug. 31 the following year*	*Non-Deep-7 Bottomfish (MUS & ECS)[2] from Jan. 1 to Dec. 31*
2012-13	10	0					
2013-14	3	0					
2014-15	2	0					
2015-16	0	0					
2016-17	1	0					
2017-18	0	0					
2018-19	2	0					
2019-20	2	0					
2020-21	0	0					

[1] Source: PIRO SFD unpublished data.
[2] On February 8, 2019, NMFS published a final rule (84 FR 2767) to reclassify certain MUS as ecosystem component species (ECS). This rule reclassified all of the non-Deep-7 bottomfish except uku as ECS.
Notes: Federal non-commercial bottomfish permit and reporting requirements became effective on August 8, 2008 (73 FR 41296, July 18, 2008). The fishing year for "Deep-7 bottomfish" begins September 1 and ends August 31 the following year. For example, data for 2008 should include information from September 1, 2008, through August 31, 2009. The fishing year for non-Deep-7 bottomfish is the calendar year. "n.d." = Not available due to confidentiality.

1.6.2.3 Spiny and Slipper Lobster

Table 36. Summary of available federal logbook data for the lobster fisheries in Hawaii

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch in MHI	No. of Trips in MHI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster MUS	*Slipper lobster MUS*	*Spiny lobster MUS*	*Slipper lobster MUS*
2004	0						
2005	0						
2006	0						
2007	2	0					
2008	2	0					
2009	3	0					
2010	0						
2011	0						
2012	0	0					

Year	No. of Federal Lobster Permits Issued[1]	No. of Federal Lobster Permits Reporting Catch in MHI	No. of Trips in MHI EEZ	Total Reported Logbook Catch (lb)		Total Reported Logbook Release/Discard (lb)	
				Spiny lobster MUS	*Slipper lobster MUS*	*Spiny lobster MUS*	*Slipper lobster MUS*
2013	2	0					
2014	1	0					
2015	2	0					
2016	1	0					
2017	2	0					
2018	1	0					
2019	1	0					
2020	0	0					
2021	0	0					

[1] Source: PIRO SFD unpublished data.
"n.d." = Not available due to confidentiality.

1.6.2.4 Deepwater Shrimp

Table 37. Summary of available federal logbook data for the deepwater shrimp fishery in Hawaii

Year	No. of Federal Shrimp Permits Issued[1]	No. of Federal Shrimp Permits Reporting Catch[2]	No. of Trips in MHI EEZ	Total Reported Logbook Shrimp MUS Catch (lb)	Total Reported Logbook Shrimp MUS Release/Discard (lb)
2009	0				
2010	0				
2011	0				
2012	0	n.d.	n.d.	n.d.	n.d.
2013	3	6	80	10,520	113
2014	7	6	61	11,676	212
2015	4	3	24	13,020	261
2016	4	3	123	39,781	7,257
2017	6	4	27	5,529	74
2018	4	n.d.	n.d.	n.d.	n.d.
2019	3	3	192	23,939	0
2020	2	n.d.	n.d.	n.d.	n.d.
2021	3	n.d.	n.d.	n.d.	n.d.

[1] Source: PIRO SFD unpublished data.
[2] Permits are valid for one year from the date issued, so permits issued in 2018 may be valid for a part of 2019. The number of permits reporting catch can therefore be greater than the number issued that year.
Notes: Federal permit and reporting requirements for deepwater shrimp fisheries became effective on June 29, 2009 (74 FR 25650, May 29, 2009). "n.d." = Not available due to confidentiality. Shrimp MUS = *H. laevigatus* and *H. ensifer*. No. of trips in MHI EEZ used permit number, gear set date to determine unique trips. Total catch and discard include both within the MHI EEZ and outside of the EEZ.

1.7 STATUS DETERMINATION CRITERIA

1.7.1 Bottomfish and Crustacean Fishery

Status determination criteria (SDC), overfishing criteria, and control rules are specified and applied to individual species within a multi-species stock whenever possible. When this is not possible, they are based on an indicator species for that multi-species stock. It is important to recognize that individual species would be affected differently based on this type of control rule, and it is important that for any given species, fishing mortality (F) does not currently exceed a level that would result in excessive depletion of that species. No indicator species are used for the bottomfish multi-species stock complexes. Instead, the control rules are applied to each stock complex as a whole.

The maximum sustainable yield (MSY) control rule is used as the maximum fishing mortality threshold (MFMT). The MFMT and minimum stock size threshold (MSST) are specified based on the recommendations of Restrepo et al. (1998) and both are dependent on the natural mortality rate (*M*). The value of *M* used to determine the reference point values is not specified in this section. The latest estimate published annually in the annual SAFE report is used, and the value is occasionally re-estimated using the best available information. The range of *M* among species within a stock complex is taken into consideration when estimating and choosing the *M* to be used for the purpose of computing the reference point values.

In addition to the thresholds MFMT and MSST, a warning reference point, B_{FLAG}, is specified at some point above the MSST to provide a trigger for consideration of management action prior to B_{FLAG} reaching the threshold. MFMT, MSST, and B_{FLAG} are specified as indicated in Table 38. Note that the MFMT listed here only applies to Hawaiian bottomfish.

Table 38. Overfishing threshold specifications for Hawaiian bottomfish and NWHI lobsters

MFMT	MSST	B_{FLAG}
$F(B) = \frac{F_{MSY} B}{c\, B_{MSY}}$ for $B \le c\, B_{MSY}$ $F(B) = F_{MSY}$ for $B > c\, B_{MSY}$	$c\, B_{MSY}$	B_{MSY}
where c = max (1-M, 0.5)		

Standardized values of fishing effort (E) and catch-per-unit-effort (CPUE) are used as proxies for F and B, respectively, so E_{MSY}, $CPUE_{MSY}$, and $CPUE_{FLAG}$ are used as proxies for F_{MSY}, B_{MSY}, and B_{FLAG}, respectively.

In cases where reliable estimates of $CPUE_{MSY}$ and E_{MSY} are not available, they would be estimated from catch and effort times series, standardized for all identifiable biases. $CPUE_{MSY}$ would be calculated as half of a multi-year average reference CPUE, called $CPUE_{REF}$. The multi-year reference window would be objectively positioned in time to maximize the value of $CPUE_{REF}$. E_{MSY} would be calculated using the same approach or, following Restrepo et al. (1998), by setting E_{MSY} equal to E_{AVG}, where E_{AVG} represents the long-term average effort prior to declines in CPUE. When multiple estimates are available, the more precautionary option is typically used.

Since the MSY control rule specified here applies to multi-species stock complexes, it is important to ensure that no species within the complex has a mortality rate that leads to excessive depletion. In order to accomplish this, a secondary set of reference points is specified to evaluate stock status with respect to recruitment overfishing. A secondary "recruitment overfishing" control rule is specified to control fishing mortality with respect to that status. The rule applies only to those component stocks (species) for which adequate data are available. The ratio of a current spawning stock biomass proxy ($SSBP_t$) to a given reference level ($SSBP_{REF}$) is used to determine if individual stocks are experiencing recruitment overfishing. SSBP is CPUE scaled by percent mature fish in the catch. When the ratio $SSBP_t/SSBP_{REF}$, or the "SSBP ratio" (SSBPR) for any species drops below a certain limit ($SSBPR_{MIN}$), that species is considered to be recruitment overfished and management measures will be implemented to reduce fishing mortality on that species. The rule applies only when the SSBP ratio drops below the $SSBPR_{MIN}$, but it will continue to apply until the ratio achieves the "SSBP ratio recovery target" ($SSBPR_{TARGET}$), which is set at a level no less than $SSBPR_{MIN}$. These two reference points and their associated recruitment overfishing control rule, which prescribe a target fishing mortality rate ($F_{RO\text{-}REBUILD}$) as a function of the SSBPR, are specified as indicated in Table 39. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 39. Recruitment overfishing control rule specifications for the BMUS in Hawaii

$F_{RO\text{-}REBUILD}$	$SSBPR_{MIN}$	$SSBPR_{TARGET}$
$F(SSBPR) = 0$ for $SSBPR \leq 0.10$ $F(SSBPR) = 0.2\ F_{MSY}$ for $0.10 < SSBPR \leq SSBPR_{MIN}$ $F(SSBPR) = 0.4\ F_{MSY}$ for $SSBPR_{MIN} < SSBPR \leq SSBPR_{TARGET}$	0.20	0.30

The Council adopted a rebuilding control rule for the NWHI lobster stock, which can be found in the supplemental overfishing amendment to the Sustainable Fisheries Act omnibus amendment on the Council's website.

1.7.2 Current Stock Status

1.7.2.1 Deep-7 Bottomfish Management Unit Species Complex

Despite availability of catch and effort (from which CPUE is derived), some life history, and fishery independent information, the MHI Deep-7 BMUS complex is still considered as data moderate. The stock assessment is conducted on a subset of the population that is being actively managed because of the closure of the NWHI to commercial fishing. The assessment is also conducted on the Deep-7 species complex because the State of Hawaii designates the seven species together, and a typical bottom fishing trip is comprised primarily of these seven species.

Generally, data are only available on commercial fishing and associated CPUE by species. The 2021 update stock assessment by PIFSC utilized a state-space surplus production model with explicit process and observation error terms (Syslo et al. 2021). Determinations of overfishing and overfished status were made by comparing current biomass and harvest rates to MSY-based reference points. As of 2018, the MHI Deep-7 bottomfish complex is not subject to overfishing and is not overfished (Table 40).

Table 40. Stock assessment parameters for the MHI Deep-7 bottomfish complex (Langseth et al. 2018)

Parameter	Value	Notes	Status
MSY for total catch	1.025 ± 0.487	Mean ± std. error, units in million lb	
MSY for reported catch	473,000 ± 225,000	Mean ± std. error, units in lb	
H_{2018}	3.0%		
H_{MSY}	6.8% ± 2.6%	Mean ± std. error	
H/H_{MSY}	0.37		No overfishing occurring
B_{2018}	21.88	Mean, units in million lb	
B_{MSY}	15.5 ± 5.0	Mean ± std. error, units in million lb	
B/B_{MSY}	1.43		Not overfished

1.7.2.2 Uku

In 2016, 27 species of Hawaii reef fish and non-Deep-7 bottomfish were assessed by PIFSC using a length-based spawning potential ratio (SPR) method, with overfishing limits calculated as the catch level required to maintain SPR = 0.30 (defined as C_{30}) using either abundance from diver surveys or commercial catch estimates (Nadon 2017). Since the assessment was finalized, only one species (uku, *Aprion virescens*) remains a MUS due to the ecosystem component amendment to the FEPs (84 FR 2767, February 8, 2019). The assessment indicated that the uku stock around Hawaii was not experiencing overfishing.

In 2020, PIFSC performed a stock assessment only on uku in the MHI using the Stock Synthesis 3.30 modeling framework, an integrated statistical catch-at-age model that fits a population model to relative abundance and size composition data in a likelihood-based statistical framework to generate maximum likelihood estimates of population parameters (Nadon et al. 2020). The assessment concluded that the MHI uku stock is not overfished and is not experiencing overfishing. Results from the uku assessment are presented in Table 41, where “SSB” refers to spawning stock biomass.

Table 41. Results from 2020 stock assessment for MHI uku (Nadon et al. 2020)

Parameter	Value	Notes	Status
MSY	93	Units mt	
F_{2018} (age 5-30)	0.08	Units yr^{-1}	
F_{MSY} (age 5-30)	0.14	Units yr^{-1}	
F_{2018}/F_{MSY}	0.57		No overfishing occurring
SSB_{2018}	819	Units mt	
SSB_{MSST}	301	Units mt	
SSB_{2018}/SSB_{MSST}	2.7		Not overfished

1.7.2.3 Crustacean

The application of the SDCs for the crustacean MUS has only been specified for the NWHI lobster stock, which is no longer a federal MUS. Previous studies conducted in the MHI estimated the MSY for spiny lobsters at approximately 15,000 – 30,000 lobsters per year of 8.26 cm carapace length or longer (WPFMC 1983). There are insufficient data to estimate MSY values for MHI slipper lobsters. MSY for MHI deepwater shrimp has been estimated at 40 kg/nm^2 (Ralston and Tagami 1992).

A stock assessment model was conducted by PIFSC in 2018 for Kona crab stock in the MHI (Kapur et al. 2019). This assessment used a Bayesian state-space surplus production model to estimate parameters needed to determine stock status. Based on this, the Kona crab stock is not overfished, and overfishing is not occurring (Table 42). For crustacean MUS, the most recent MSY estimates are found in Table 43.

Table 42. Stock assessment parameters for the Hawaiian Kona crab stock (Kapur et al. 2019)

Parameter	Value	Notes	Status
MSY for total catch	73,069	In lb	
MSY for reported catch	25,870	In lb	
H_{2016}	0.0081	Expressed as proportion	
H_{MSY}	0.114	Expressed as proportion	
H/H_{MSY}	0.0714		No overfishing occurring
B_{2016}	885,057	In lb	
B_{MSY}	640,489	In lb	
B_{2016}/B_{MSY}	1.3977		Not overfished

Table 43. Best available MSY estimates for the Crustacean MUS in Hawaii

Fishery	Management Unit Species	MSY (lb)
Crustacean	Deep-water shrimp	275,575
Crustacean	Kona crab	73,069

Sources: Deepwater shrimp (Tagami and Ralston 1988); Kona crab (Kapur et al. 2019).

1.8 OVERFISHING LIMIT, ACCEPTABLE BIOLOGICAL CATCH, AND ANNUAL CATCH LIMITS

1.8.1 Brief description of the ACL process

The Council developed a tiered system of control rules to guide the specification of ACLs and accountability measures (AMs; WPRFMC 2011). The process utilizes the best scientific information available (BSIA) in the form of, but not limited to, stock assessments, published papers, reports, and/or available data. Available data are categorized into the different tiers in the control rule ranging from Tier 1 (i.e., most information available, typically a stock assessment) to Tier 5 (i.e., catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties associated with the assessment to specify the Acceptable Biological Catch (ABC), lowering the MSY-based overfishing limit (OFL) to the ABC. A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties associated with the SEEM factors, and a buffer is used to lower the ABC to an ACL. For Tier 4, which is comprised of stocks with MSY estimates but low activity fisheries, the control rule is 91 percent of MSY. For Tier 5, which has catch-only information, the control rule is a one-third reduction in the median catch depending on a qualitative evaluation of stock status via expert opinion. ACLs may be derived from a variety of methods including the above mentioned SEEM analysis or a percentage buffer (i.e., percent reduction from ABC based on expert opinion) or the use of an annual catch target (ACT). NMFS typically implements ACLs on an annual basis, but the Council normally recommends a multi-year specification.

The AM typically implemented for Hawaii insular fisheries is a post-season AM in the form of an overage adjustment. If the recent three-year average catch for a fishery exceeded the implemented ACL, the subsequent ACL is downward adjusted by the amount of overage. A three-year average of recent catch is utilized as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to data quality and outliers. The uku and Kona crab fisheries, however, also have an in-season AM where, if the catch is projected to reach the implemented ACT, the fishery will be closed in federal waters for the remainder of the fishing year. Similarly, an in-season AM for precious coral fisheries will close individual coral beds if the ACL for that bed is projected to be reached.

1.8.2 Current OFL, ABC, ACL, and Recent Catch

The most recent implementation of OFLs, ABCs, and ACLs covers fishing years 2019–2021 for the MHI Deep-7 bottomfish stock complex (84 FR 29394, June 24, 2019), 2020–2023 for Kona crab (85 FR 79928, December 11, 2020), 2019–2021 for uku, 2019–2021 for deepwater shrimp, and 2019–2021 for precious corals (85 FR 26622, May 5, 2020). The fisheries for deep sea precious corals remain inactive except for limited harvest of black corals. ACLs are no longer specified for coral reef species nor several crustacean species due to the recent ECS amendment (84 FR 2767, February 9, 2019). It is also of note that the MHI Deep-7 stock complex operates based on fishing year and is still open for the 2021–2022 fishing year. The ACT for Kona crab was newly implemented as of the most recent specification, and any projected exceedance of the ACT will result in a federal fishery closure for the species. The ACLs shown in Table 44 are the most recently implemented ACLs by NMFS. Recent average catch for the MHI Deep-7

Bottomfish stock complex (169,003 lb) accounted for 34.3% of its implemented ACL (492,000 lb; Table 44).

Table 44. ACLs for Hawaii MUS in 2021 and three-year recent average catch (lb) from 2019–2021

Fishery	Management Unit Species	OFL	ABC	ACL	ACT	Catch
Bottomfish	MHI Deep-7 stock complex	558,000	508,000	492,000	-	164,171
	Aprion virescens (uku)	132,277	127,205	127,205	-	66,137
Crustacean	Deepwater shrimp	-	250,773	250,773	-	n.d.
	Kona crab	33,989	30,802	30,802	25,491	4,570
Precious Coral	‘Au‘au Channel black coral	-	7,508	5,512	-	n.d.
	Makapu‘u Bed pink coral	-	3,009	2,205	-	n.d.
	Makapu‘u Bed bamboo coral	-	571	551	-	n.d.
	180 Fathom Bank pink coral	-	668	489	-	n.d.
	180 Fathom Bank bamboo coral	-	126	123	-	n.d.
	Brooks Bank pink coral	-	1,338	979	-	n.d.
	Brooks Bank bamboo coral	-	256	245	-	n.d.
	Ka‘ena Point Bed pink coral	-	201	148	-	n.d.
	Ka‘ena Point Bed bamboo coral	-	37	37	-	n.d.
	Keāhole Bed pink coral	-	201	148	-	n.d.
	Keāhole Bed bamboo coral	-	37	37	-	n.d.
	Hawaii Exploratory Area precious corals	-	2,205	2,205	-	n.d.

Notes: “n.d.” indicates that the data could not be disclosed due to issues with data confidentiality (i.e., less than three licenses reporting). “-” indicates that there is no value for the given parameter (i.e., not estimated or implemented). Catch for the MHI Deep-7 stock complex is for the 2020–2021 fishing year only and not a three-year average.

1.9 BEST SCIENTIFIC INFORMATION AVAILABLE

1.9.1 Main Hawaiian Island Deep-7 Bottomfish Fishery

1.9.1.1 Stock Assessment Benchmark

In 2018, PIFSC completed a benchmark stock assessment for the MHI Deep-7 bottomfish fishery (2018 stock assessment) using data through 2015 (Langseth et al. 2018). The 2018 stock assessment used a Bayesian state-space surplus production model and included several improvements, such as updated filtering and standardization methods for CPUE from commercial data based on a series of workshops that included input from various management, scientific, and industry participants (Yau 2018). It also incorporated a fishery-independent estimate of abundance as estimated from Richards et al. (2016).

The 2018 assessment estimated a maximum sustainable yield (MSY) for reported catch of 509,000 lb for the MHI Deep-7 bottomfish stock complex. The 2018 stock assessment also included projection results of a range of commercial catches of Deep-7 bottomfish that would produce probabilities of overfishing ranging from 0 percent to 100 percent at 1 percent intervals. If 558,000 lb of reported catch occur from fishing years 2018-2022, there is a 50% risk of overfishing in 2022; this is the overfishing limit.

The next benchmark stock assessment for the MHI Deep-7 bottomfish complex will be completed in 2023.

1.9.1.2 Stock Assessment Updates

In 2021, PIFSC completed a stock assessment update for the MHI Deep-7 bottomfish fishery (2021 stock assessment) using data through 2018 (Syslo et al. 2021). The 2021 stock assessment used a Bayesian state-space surplus production model and included several improvements, such as updated filtering and standardization methods for CPUE from commercial data based on a series of workshops that included input from various management, scientific, and industry participants (Yau 2018). It also incorporated a fishery-independent estimate of abundance as estimated from Richards et al. (2016).

The 2021 assessment estimates MSY for reported catch of 473,000 lb for the MHI Deep-7 bottomfish stock complex. The 2021 stock assessment also included projection results of a range of commercial catches of Deep-7 bottomfish that would produce probabilities of overfishing ranging from 0 percent to 100 percent at 1 percent intervals. If 618,000 lb of reported catch occurs from fishing years 2021–2025, there is a 50% risk of overfishing in 2021; this is the overfishing limit.

1.9.1.3 Best Available Scientific Information

National Standard 2 requires that conservation and management measures be based on the BSIA and be founded on comprehensive analyses. National Standard 2 guidelines (78 FR 43087, July 19, 2013) state that scientific information that is used to inform decision making should include an evaluation of its uncertainty and identify gaps in the information (50 CFR 600.315(a)(1). The guidelines also recommend scientific information used to support conservation and management be peer reviewed (50 CFR 600.315(a)(6)(vii)). However, the guidelines also state that mandatory management actions should not be delayed due to limitations in the scientific information or the promise of future data collection or analysis (50 CFR 600.315(a)(6)(v)).

The PIFSC determined that the 2021 benchmark stock assessment by Syslo et al. (2021) was the BSIA. This is based on the assessment passing a Western Pacific Stock Assessment Review by a three-person independent peer review panel.

1.9.2 Uku Fishery

1.9.2.1 Stock Assessment

In February 2017, PIFSC released the final species level assessment for the main Hawaiian Islands (Nadon 2017). This assessment covers 27 species of fishes, one of which is uku (*Aprion virescens*). The remaining 26 species are no longer MUS.

The 2017 assessment utilized a different approach compared to the existing model used for the fishing years 2015-2018 specification. It used life history information and a length-based approach to obtain stock status based on SPR rather than MSY. When life history information is not available for a species, a data-poor approach is used to simulate life history parameters based on known relationships (Nadon and Ault 2016). Fishery independent size composition and abundance data from diver surveys were combined with fishery dependent catch estimates to calculate current fishing mortality rates (F), SPR, SPR-based sustainable fishing rates (F_{30}; F resulting in SPR = 30%), and catch levels corresponding to these sustainable rates (C_{30}). A length-based model was used to obtain mortality rates and a relatively simple age-structured population model to find the various SPR-based stock status metrics. The catch level to maintain the population at SPR=30%, notated as C_{30}, was obtained by combining F_{30} estimates with current population biomass estimates derived directly from diver surveys or indirectly from the total catch. The OFL to a 50% risk of overfishing was defined as the median of the C_{30} distribution.

In May 2020, PIFSC released the final species level assessment for the main Hawaiian Islands uku stock. This assessment built off previous assessment efforts and used catch, CPUE, diver surveys, and size composition time series in the Stock Synthesis modeling framework, which is an integrated catch-at-age model.

Stock Synthesis uses observed catch, size/age composition, and relative abundance indices, such as CPUE, as inputs and incorporates the main population processes (e.g., mortality, selectivity, growth) to recreate population biomass trajectory and derived indicators of stock status to be measured against reference points in the Hawaii FEP. The 2020 assessment results differed slightly from the 2017 assessment that used a data-limited approach on mean length data only, as the 2020 assessment estimated a lower recent fishing mortality rate of approximately 0.08 versus 0.15 for the 2017 assessment. The 2020 stock assessment determined a higher OFL than the 2017 assessment based on catch-derived biomass, though the SPR-based F_{MSY} proxy used in the 2017 assessment (F_{30} = 0.16) is close to the F_{MSY} value estimated in the 2020 assessment (0.14).

1.9.2.2 Stock Assessment Updates

There are no stock assessment updates available for uku.

1.9.2.3 Best Scientific Information Available

The Nadon et al. (2020) assessment underwent peer review by a Western Pacific Stock Assessment Review (WRSPAR) panel from February 24 to 28, 2020 (85 FR 5633, January 31, 2020). The review panel, comprised of E. Franklin, Y. Chen, and Y. Jiao was asked to review a set of 11 Terms of Reference according to guidelines established in the WPSAR framework. The assessment author revised the draft assessment addressing the WPSAR panel comments and recommendations and presented the final stock assessment document at the 136th and 182nd meetings of the SSC and Council, respectively. PIFSC and the Council consider these assessments the BSIA for these species.

1.9.3 Crustacean Fishery

1.9.3.1 Stock Assessment Benchmark

Deepwater Shrimp: The deepwater shrimp (*Heterocarpus laevigatus* and *H. ensifer*) initial resource assessment was conducted in the early 1990s by Ralston and Tagami (1992). This involved depletion experiments, stratified random sampling of different habitats, and calculation of exploitable biomass using the Ricker equation (Ricker 1975). Since then, no new estimates were calculated for this stock.

Kona Crab: A benchmark stock assessment model was completed by PIFSC scientists in 2019 (Kapur et al. 2019). This assessment utilized a Bayesian state-space surplus production model. Based on this, the Kona crab stock is not overfished and not experiencing overfishing.

PIFSC determined the Kapur et al. (2019) stock assessment to be the BSIA for Kona crabs because the assessment passed independent peer review by a WPSAR three-person panel.

1.9.3.2 Stock Assessment Updates

There are no stock assessment updates available for the crustacean MUS.

1.9.3.3 Best Scientific Information Available

To date the best available scientific information for the crustacean MUS are as follows:

- Deepwater shrimp – Ralston and Tagami (1992)
- Kona crab – Kapur et al. (2019)

1.10 HARVEST CAPACITY AND EXTENT

The MSA defines the term "optimum," with respect to the yield from a fishery, as the amount of fish which:

- Will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems.
- Is prescribed based on the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery [50 CFR §600.310(f)(1)(i)].

Optimum yield (OY) in the bottomfish fisheries is prescribed based on the MSY from the stock assessment and the best available scientific information. In the process of specifying ACLs, social, economic, and ecological factors were considered and the uncertainties around those factors defined the management uncertainty buffer between the ABC and ACL. OY for the bottomfish MUS complex is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the FEPs and used by the Council to manage the stock.

The Council recognizes that MSY and OY are long-term values whereas the ACLs are yearly snapshots based on the level of fishing mortality at MSY (F_{MSY}). There are situations when the long-term means around MSY are lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. A stock can have catch levels and catch rates exceeding that of MSY over the short-term to lower the biomass to a level around the estimated MSY and still not jeopardize the stock.

The harvest extent, in this case, is defined as the level of catch harvested in a fishing year relative to the ACL or OY. The harvest capacity is the level of catch remaining in the annual catch limit that can potentially be used for the total allowable level of foreign fishing (TALFF). Table 45 summarizes the harvest extent and harvest capacity information for Hawaii in 2021 using three-year average catch.

Table 45. Hawaii proportion of harvest capacity and extent relative to the ACL in 2021

Fishery	Management Unit Species	ACL	Catch (lb)	Harvest Extent (%)	Harvest Capacity (%)
Bottomfish	MHI Deep-7 stock complex	492,000	164,171	33.4	66.6
	Aprion virescens (uku)	127,205	66,137	52.0	48.0
Crustacean	Deepwater shrimp	250,773	n.d.	NA	NA
	Kona crab	30,802	4,570	14.8	85.2
Precious Coral	‘Au‘au Channel black coral	5,512	n.d.	NA	NA
	Makapu‘u Bed pink coral	2,205	n.d.	NA	NA
	Makapu‘u Bed bamboo coral	551	n.d.	NA	NA
	180 Fathom Bank pink coral	489	n.d.	NA	NA
	180 Fathom Bank bamboo coral	123	n.d.	NA	NA

Fishery	Management Unit Species	ACL	Catch (lb)	Harvest Extent (%)	Harvest Capacity (%)
	Brooks Bank pink coral	979	n.d.	NA	NA
	Brooks Bank bamboo coral	245	n.d.	NA	NA
	Ka‘ena Point Bed pink coral	148	n.d.	NA	NA
	Ka‘ena Point Bed bamboo coral	37	n.d.	NA	NA
	Keāhole Bed pink coral	148	n.d.	NA	NA
	Keāhole Bed bamboo coral	37	n.d.	NA	NA
	Hawaii Exploratory Area precious corals	2,205	n.d.	NA	NA

"n.d." indicates that the data could not be disclosed due to issues with data confidentiality (i.e., less than three licenses reporting). "NA" indicates that there is no value for the given parameter (i.e., not estimated or implemented). Each catch value represents the recent three-year average except for the MHI Deep-7 stock complex, which presents the catch value only for the 2020–2021 fishing year.

1.11 ADMINISTRATIVE AND REGULATORY ACTIONS

This summary describes management actions NMFS implemented for insular fisheries in the Hawaiian Archipelago during calendar year 2021.

On June 17, 2021, NMFS established the annual harvest guideline for the commercial lobster fishery in the Northwestern Hawaiian Islands (NWHI) for calendar year 2021 at zero lobsters (86 FR 32239). Regulations at 50 CFR 665.252(b) require NMFS to publish an annual harvest guideline for lobster Permit Area 1, comprised of Federal waters around the NWHI. Regulations governing the Papahānaumokuākea Marine National Monument in the NWHI prohibit the unpermitted removal of monument resources (50 CFR 404.7) and establish a zero annual harvest guideline for lobsters (50 CFR 404.10(a)). Accordingly, NMFS established the harvest guideline for the NWHI commercial lobster fishery for calendar year 2021 at zero lobsters. Harvesting NWHI lobster resources was not allowed.

On September 28, 2021, NMFS published a final rule (86 FR 53818) to enhance the protection of Hawaiian spinner dolphins and prevent their disturbance. This rule prohibits swimming with, approaching, or remaining within 50 yards of a Hawaiian spinner dolphin, including approach by interception, or placing a vessel, person, or other object in the path of a Hawaiian spinner dolphin so that the dolphin approaches within 50 yards. The final rule applies within two nautical miles from shore of the MHI and in designated waters bounded by the islands of Lanai, Maui, and Kahoolawe.

On December 16, 2021, NMFS established the annual harvest guideline for the commercial lobster fishery in the Northwestern Hawaiian Islands (NWHI) for calendar year 2022 at zero lobsters (86 FR 71395). For the reasons described above, harvesting NWHI lobster resources is not allowed in 2022.

2 ECOSYSTEM CONSIDERATIONS

2.1 COVID IMPACTS

Fishing communities and island economies across the Pacific Islands Region continued to experience pandemic-related impacts during 2021. Key metrics of recovery include tourism and unemployment, both of which drive seafood demand and have implications for fishing activity and markets. Despite these challenges, the Hawaii fishing community (commercial fishers, non-commercial fishers, seafood markets and processors) played a vital role in supporting local food systems, nutrition, food security, and promoting social cohesion. This importance is amplified in the face of natural disasters and human health crises, and fishing communities have adapted to continue these crucial functions in the face of this unprecedented disruption

In the state of Hawaii, visitor arrivals saw a significant rebound relative to 2020. There were approximately 2.5 times (153% increase) more total visitors to the State of Hawaii in 2021 (6.8 million) relative to 2020 (2.7 million)[1]. However, this still reflects a nearly 35% reduction relative to 2019. This recovery was comprised of significant increases in arrivals from domestic flights (+222%) to counter ongoing travel restrictions from international flights (-80%) in 2021 relative to 2020. The State of Hawaii experienced lingering effects from ongoing travel restrictions in early 2021 as the months of January and February 2021 saw cumulative total visitor counts during this period approximately 75% below the pre-pandemic months of January and February 2020. For 2021, total visitor spending was $13.0 billion, a drop of 26.6% from the $17.7 billion spent in 2019. Comparative 2020 visitor spending statistics were not available[2].

In terms of unemployment, Hawaii saw the largest state-level recovery in the nation during 2021. While Hawaii had the highest state-level unemployment in 2020 (over 12%), unemployment rates dropped to around 6% during 2021, largely due to relaxed travel and business restrictions.

A cost-earnings survey was implemented for Hawaii small boat fisheries during 2021, and an open-ended question solicited input from the community on pandemic-related impacts on fishing activities. While the survey focused on 2020, many responses were likely still relevant in 2021. Self-reported pandemic-related impacts were mixed across the fishery as nearly 40% indicated that they fished less, 34% indicated no changes to fishing activities, and 6% fished more. Some fishers reported giving away more fish and consuming more of their catch, while sales within the community was slightly higher for some fishers. Pandemic-related influences mentioned by fishers affecting their activities included low demand and restaurant closures.

In 2021, inflation-adjusted[3] Hawaii non-longline commercial landings and revenues for pelagic and insular fisheries were up about 12% and 40%, respectively, from 2020, with overall market prices approximately 16% higher than 2020. The emergence of the Omicron variant of COVID likely impacted activity later in the year as December 2021 revenues were down 12% relative to December 2020. Despite the initial recovery, inflation-adjusted non-longline commercial revenues were down about $2 million, or about 8%, relative to a five-year (2015 to 2019) pre-pandemic baseline. The socioeconomic module includes more specific details on the economic performance for bottomfish and ecosystem component species in 2021.

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[1] https://files.hawaii.gov/dbedt/visitor/tourism/2021/Dec21.pdf.
[2] https://dbedt.hawaii.gov/blog/22-03/.
[3] Using GDP implicit price deflator: https://fred.stlouisfed.org/series/GDPDEF.

2.2 FISHER OBSERVATIONS

Hawaii fishermen Clay Tam and Roy Morioka started the fisher observations initiative in 2020 to add traditional and local ecological knowledge, and on-the-water observations to fishery-dependent data sources in the annual SAFE reports. Fisher observations from 2020 can be found in the pelagic and the respective archipelagic reports (WPRFMC 2021a; WPRFMC 2021b; WPRFMC 2021c; WPRFMC 2021d).

In 2021, the Council collected archipelagic fisher observations during quarterly advisory panel meetings for Hawaii. Input collected by fishers during these meetings was limited to Advisory Panel members. The Council also convened a meeting dedicated to Hawaii fisher observations on February 24, 2022. This meeting included Hawaii Advisory Panel members but also included other individuals from Hawaii fishing communities. The full results from these fisher observation meetings will be made available as a PIFSC data report. Hawaii archipelagic fisher observations from 2021 presented here will begin with a summary of information from quarterly advisory panel meetings, separated by island, followed by a summary of archipelagic fisher observations data collected from the February meeting.

2.2.1 Information from Advisory Panel Meetings

2.2.1.1 Hawaii Island

In the summer, only two manta rays were observed at Keahole, when there are usually 12 around, while 5-6 mantas are consistently found around the Sheraton. In the fall around Kona, there was an observed increase in halalu. Halalu were under the boat nearly anywhere one anchored. The currents were strong around Kona.

2.2.1.2 Kauai

In the summer, there were issues with jet skis coming too close to shore, which caused conflicts. Rock Quarry Beach is now owned by Mark Zuckerberg, so fishers were confronted by his security. Other wealthy landowners are also attempting to restrict beach access to public spaces. Limited parking at harbors such as Hanalei is causing hostility in those areas. Swimmers in the boat channels was a persistent issue and concerning to fishers. Fall conditions were good for bottomfish fishing. Boat ramps remained busy every weekend and demand for fresh fish remained strong.

2.2.1.3 Maui

In the spring, the Maui cooperative fishers were still bottomfish fishing, but they were not catching much because the markets were slow; however, one bottomfish fisher present did not have trouble selling catch. In the summer, there was uncertainty surrounding if the new sunscreen ban was being enforced. During the fall, bottomfish fishers mostly took day trips amidst an increase of imported fish in the markets. The fisheries were described as slow, but it was unclear if this was caused by a lack of fish or poor weather.

2.2.1.4 Oahu

Early in the year, the weather made fishing tough, and the currents were bad for fishing at the Penguin Banks. In the spring, sharks were prevalent. Additionally, opakapaka could still be found around Haleiwa, perhaps because of the water temperature, but opakapaka are usually gone by the spring. Shark depredation continued to occur. A fisher reported the opakapaka fishing was not good, but prices were in the $20 per pound range. An advisory panel member noted that Kahaluu beach park was closed due to coral spawning under the guise that restricting access would improve spawning. The same individual reported that uku were biting and that he was getting $7 per pound for the species; this fisher also noted that 2021 will likely be an anomaly due to COVID impacts and regulatory changes. During the summer, shoreline fishers were still waiting for halalu and oama to arrive. Later in the summer, the halalu came in, but the oama was late. Overall, fewer fish were reported in Hanauma Bay. In the fall, one advisory panel member observed an increase in ‘ōʻio (i.e., bonefish) along with kona crab. Bottomfish fishing was slow on Oahu, which may have been due to lower prices. One advisory panel member observed more ‘ōʻio tagged around Hawaii Kai through October. A fisher caught an onaga that was spawning late in the fall, which was unusual for that time of year.

2.2.2 Information from the Annual Summit

On February 24, 2022 from 6:30 to 8:30 pm Hawaii Standard Time, the Council convened a fisher observations meeting with advisory panel members from Hawaii along with other members of the fishing community. Hawaii fishermen Clay Tam and Roy Morioka convened and facilitated the meeting, and it was attended by 11 Hawaii fishers or fisher representatives, Council staff, staff from the HDAR, and three PIFSC staff. The focus of the meeting was to describe notable fishery events, changes in timing of fisheries events, issues to which the Council should pay attention, and consideration for causes of any changes. Discussions were based upon an interview guide developed by advisory panel members, Council staff, and PIFSC staff members on the Council's Social Science Planning Committee (SSPC). Participants were asked follow up questions as needed related to different social, economic, ecological, and management (SEEM) aspects of the fishery to facilitate their use in fisheries science and management. These four SEEM categories comprise a qualitative construct which have been used to complement the quantitative P* construct and process, and provide additional guidance when setting annual catch limits (Hospital et al. 2019).

The Hawaii fisher observations meeting was not recorded, but PIFSC staff along with Council staff took detailed notes during the meeting and captured attendee quotes verbatim when possible, and if not verbatim, at least captured all main ideas. Main ideas were categorized topically using the SEEM categories, then into additional sub-categories to provide further detail on fisher observations from Hawaiʻi fishers in 2021. Below, their observations of archipelagic fisheries are separated and described using the SEEM categories.

2.2.2.1 Social

COVID-19 and boat ramp/shoreline access conflicts were the primary social issues in 2021 identified by Hawaii fishers. One Maui fisher reported that he built a custom electric reel setup for a jet ski fisher. The individual was catching bottomfish off of the ski. Kauai fishers reported seeing a big school of akule that persisted all summer in Kalihiwai. Fishers caught and shared akule all summer, taking only what they need and sharing it within the community. One Maui bottomfish fisher cancelled their CML since there were no markets for bottomfish without the presence of tourists. Kauai fishers reported more conflicts at boat ramps as visitor arrivals increased. Another Kauai fisher reported that wealthy landowners were attempting to close down shoreline access to local families, which caused them to travel further to go fishing.

2.2.2.2 Economic

A Maui fisher observed that he did not find Deep-7 bottomfish in the markets in 2021. The wholesale prices were so high that markets were not selling them, so it was unclear where the fish were going if not to the retail stores. Some markets on Maui closed but some new ones opened since the pandemic began. On Oahu, kalekale prices were good at the auction with reports of fishers selling them for $2 to $3 more per pound. An individual thought that it was interesting that the local buyers were willing to pay higher prices for kalekale. An Oahu fisher reported good prices for onaga and large opakapaka in 2021. The market was not as strong in Hilo, where one fisher reported variable demand and markets refusing opakapaka at times. Fishing costs were high as fuel prices and supply chain issues increased fishing costs.

2.2.2.3 Ecological (Biological and Physical/Oceanographic)

An Oahu bottomfish fisher reported strong recruitment for onaga and ehu through June, with good abundance for market-size onaga (2 to 4 pounds) and mid-to-large ehu (greater than 2 pounds). Another Oahu fisher indicated that he observed large opakapaka towards the end of 2021 but not in groups. A different bottomfish fisher reported catching larger kalekale in the 2-3 pound range. In Hilo, shoreline fishers did well, catching ulua and lots of fish. Some headed to the Ka‘u side to fish during a north swell. A Kona bottomfish fisher who only fishes on the weekends felt that bottomfish fishing was changing, noting different fish, smaller fish, and different sizes than had been seen in the past 10 to 15 years. An Oahu bottomfish fisher felt that 2021 was a continuation of 2020 findings, with onaga being available when weather, fish, current, and lack of predators all aligned.

In Kona, one fisher noted an increase in bait, similar to what had been seen in the 1980s. The same fisher reported seeing a large aggregation of squid, the largest he had ever seen near Kona. On Kauai, a fisher also reported increases in baitfish. Oahu fishers noted a lack of opelu in their usual areas, but Hilo fishers observed a large number of opelu in 2021. An Oahu fisher felt that the changes in baitfish may be affecting the opakapaka fishery, but it was too early to tell. Another Oahu fisher had difficulty catching opakapaka around the island, finding only one school of 3 to 5 pound fish all year long. The fishers present heard similar reports from other fishers targeting opakapaka off of Sandy Beach and Allen Davis. The fisher felt that the opakapaka were not aggregating in areas and times when they usually do. As a result, the fisher only caught opakapaka incidentally during the daytime with the larger fish mixed in with onaga at times during the year. Oama were present at the Hawaii Kai boat ramp in February despite them normally arriving in August. A Kona fisher also reported that Kona crab were “early” too.

Shark depredation remained a concern for bottomfish fishers targeting opakapaka on the Penguin Banks. A fisher reported that he could not get away from sharks, and it did not matter whether he was anchored or drifting. Shark depredation also made uku fishing on the banks difficult. One fisher reported catching 2 to 3 uku before the Galapagos sharks arrived. During one trip, the individual reported 13 fish hooked, but only landed a couple due to sharks. Another Oahu fisher observed a greater abundance of sharks, particularly at depth, suggesting that sandbar sharks were to blame for the deeper depredation events. Another fisher reported that sharks ended opakapaka and uku fishing trips where they anchored but noted a decrease in depredation late in the year as the water cooled. A part-time bottomfish fisher had luck catching gindai with no shark depredation, but he noted that he was not fishing in normal fishing areas.

In Hilo, one bottomfish fisher reported some odd species being harvested including a mizu ika (i.e., diamondback squid) greater than 30 pounds. The fish look like a kite, and they are rarely seen or caught.

In terms of currents, a Kona fisher reported dirty water, perhaps due to the Ka‘u current. The Ka‘u current made the surrounding currents softer on the fishing grounds, which one fisher felt negatively affected bottomfish fishing. Another Kona fisher agreed, noting that the Kohala current is the return current, which is what is needed for good fishing. The winds on the Hamakua side prevented bottomfish fishing trips to that coast. One Kona fisher reported that he did not fish much during the second half of the year because the winds. According to one Oahu fisher, the currents were generally good with a few exceptions around Oahu. Despite the good currents, the weather still limited Deep-7 bottomfish fishing trips. One fisher reported fewer than ten 10 to 15 knot wind days, which are the conditions most favorable for Deep-7 fishing. Another Oahu fisher reported not fishing from July to November due to poor wind conditions. An Oahu fisher was hopeful for 2022, noting that opakapaka schools were being observed at the Penguin Banks again. The fisher hypothesized that their absence may have been related to a prolonged period of higher sea surface temperatures which affected abundance of hauliuli and pyrosomes associated with schooling opakapaka. With sea surface temperatures dropping to under 80 degrees Fahrenheit, fishers noted both forage species returned in January 2022.

2.2.2.4 Management

There were no comments from fishers pertaining to management.

2.2.2.5 New Gear/Technology

Radar for small boats have allowed new bottomfish fishers to sight Deep-7 fishers and spots that were previously only known to older fishers. Greater adoption of electric reels and line counters have been noted as a possible cause for the general decline in Deep-7 prices.

2.3 CORAL REEF FISH ECOSYSTEM PARAMETERS

2.3.1 Regional Reef Fish Biomass and Habitat Condition

Description: "Reef fish biomass" is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2019. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

Rationale: Reef fish biomass has been widely used as an indicator of relative ecosystem status and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: American Samoa, Guam, Commonwealth of the Northern Mariana Islands (CNMI), Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), and Pacific Remote Island Areas (PRIA)

Spatial Scale: Regional

Data Source: Data used to generate cover and biomass estimates come from visual surveys conducted by the National Marine Fisheries Service (NMFS) Pacific Island Fisheries Science Center (PIFSC) Ecosystem Sciences Division (ESD) and their partners as part of the Pacific Reef Assessment and Monitoring Program (RAMP). Survey methods are described in detail in Ayotte et al. (2015). In brief, they involve teams of divers conducting stationary point count cylinder (SPC) surveys within a target domain of < 30 meter hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only data from forereef habitats are used. At each SPC, divers record the number, size, and species of all fishes within or passing through paired 15 meter-diameter cylinders over the course of a standard count procedure.

Fish sizes and abundance are converted to biomass using standard length-to-weight conversion parameters, taken largely from FishBase and converted to biomass per unit area by dividing by the area sampled per survey. Site-level data were pooled into island-scale values by first calculating mean and variance within strata, and then calculating weighted island-scale mean and variance using the formulas given in Smith et al. (2011) with strata weighted by their respective sizes.

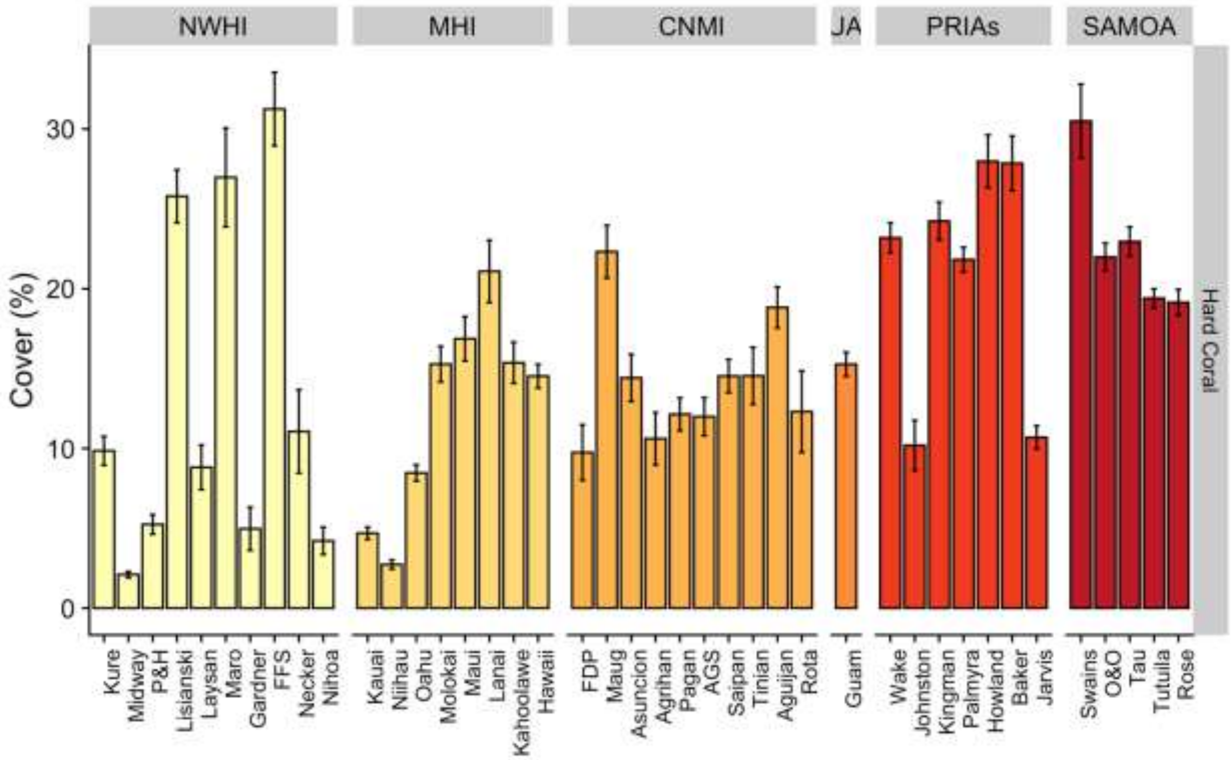

Figure 1. Mean coral cover (%) per U.S. Pacific Island averaged over the years 2010-2019 by latitude

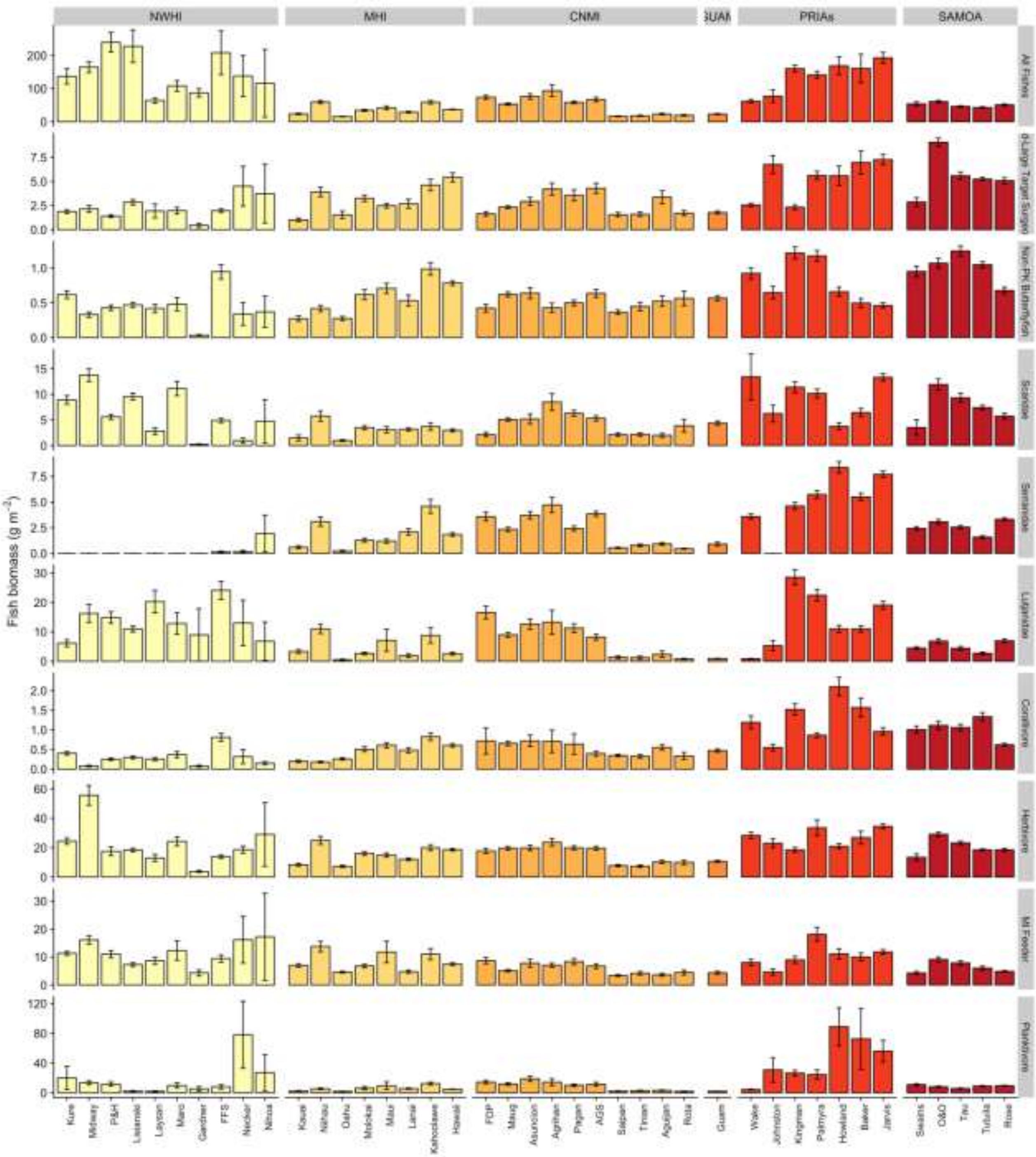

Figure 2. Mean fish biomass (g/m^2 ± standard error) of functional, taxonomic, and trophic groups by U.S. Pacific reef area from the years 2010-2019 by latitude. The group Serranidae excludes planktivorous members of that family – i.e., anthias, which can by hyper-abundant in some regions. Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group – as high biomass of that species at Wake overwhelms corallivore biomass at all other locations. The group "MI Feeder" consists of fishes that primarily feed on mobile invertebrates

2.3.2 Main Hawaiian Islands Reef Fish Biomass and Habitat Condition

Description: "Reef fish biomass" is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2019. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

Rationale: Reef fish biomass has been widely used as an indicator of relative ecosystem status and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: MHI

Spatial Scale: Island

Data Source: Data used to generate biomass and cover estimates comes from visual surveys conducted by NOAA PIFSC ESD and partners, as part of the Pacific RAMP. Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.3.1.

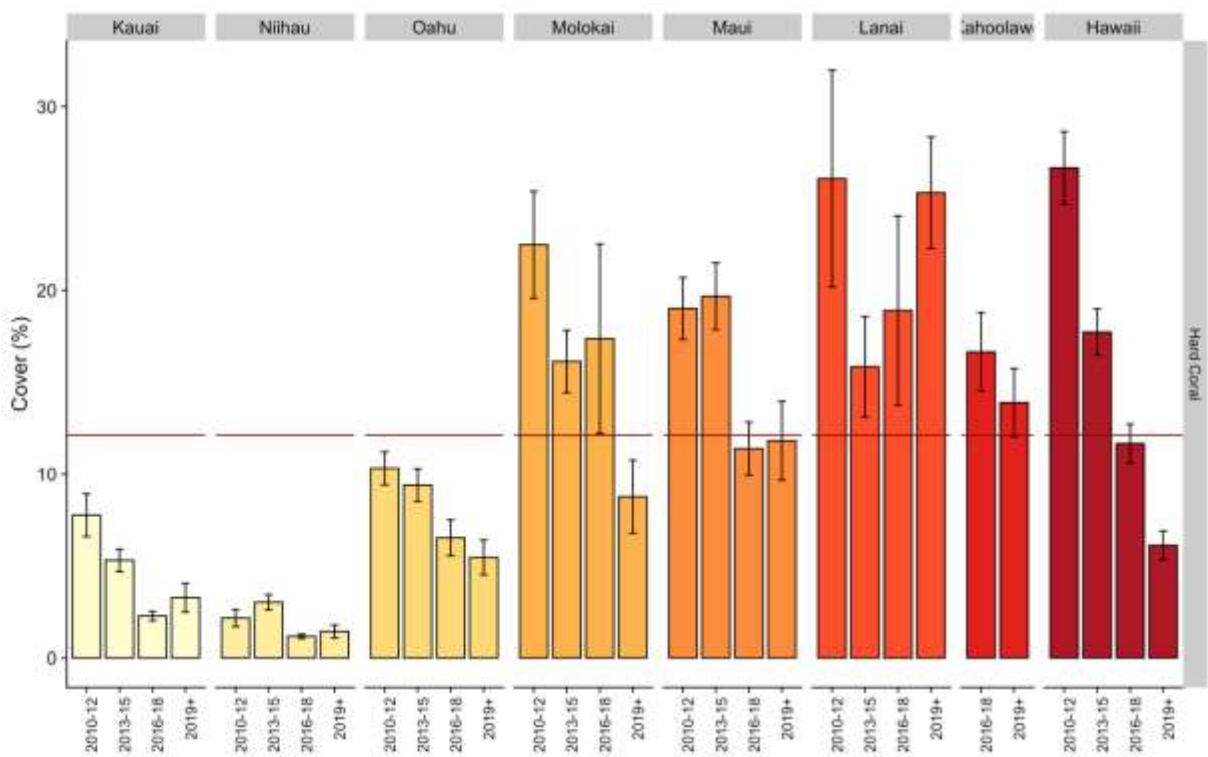

Figure 3. Mean coral cover (%) per island averaged over the years 2010-2019 by latitude with MHI mean estimates plotted for reference (red line)

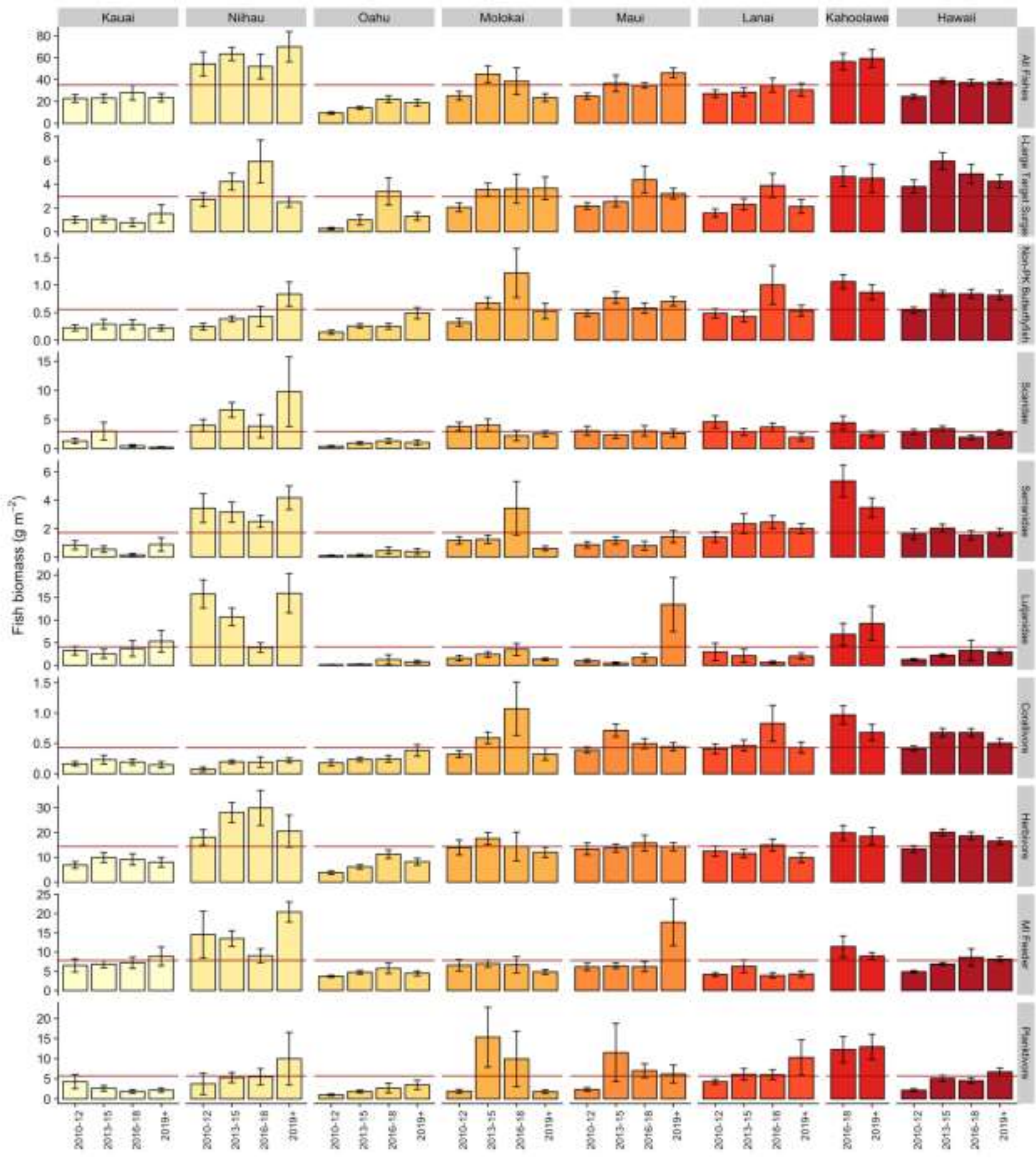

Figure 4. Mean fish biomass (g/m^2 ± standard error) of MHI functional, taxonomic, and trophic groups from the years 2010-2019 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). The group "MI Feeder" consists of fishes that primarily feed on mobile invertebrates; with MHI mean estimates plotted for reference (red line)

2.3.3 Northwestern Hawaiian Islands Reef Fish Biomass and Habitat Condition

Description: "Reef fish biomass" is mean biomass of reef fishes per unit area derived from visual survey data between 2010 and 2020. Hard Coral cover is mean cover derived from visual estimates by divers of sites where reef fish surveys occurred. No new surveys occurred in 2020 or 2021 due to COVID-19 and the numbers presented here are identical to the 2019 report.

Rationale: Reef fish biomass has been widely used as an indicator of relative ecosystem status and has repeatedly been shown to be sensitive to changes in fishing pressure, habitat quality, and oceanographic regime. Hard coral cover is an indicator of relative status of the organisms that build coral reef habitat and has been shown to be sensitive to changes in oceanographic regime, and a range of direct and indirect anthropogenic impacts. Most fundamentally, cover of hard corals has been increasingly impacted by temperature stress as a result of global heating.

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: NWHI

Spatial Scale: Island

Data Source: Data used to generate biomass and cover estimates comes from visual surveys conducted by NOAA PIFSC ESD and partners, as part of the Pacific RAMP. Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.3.1.

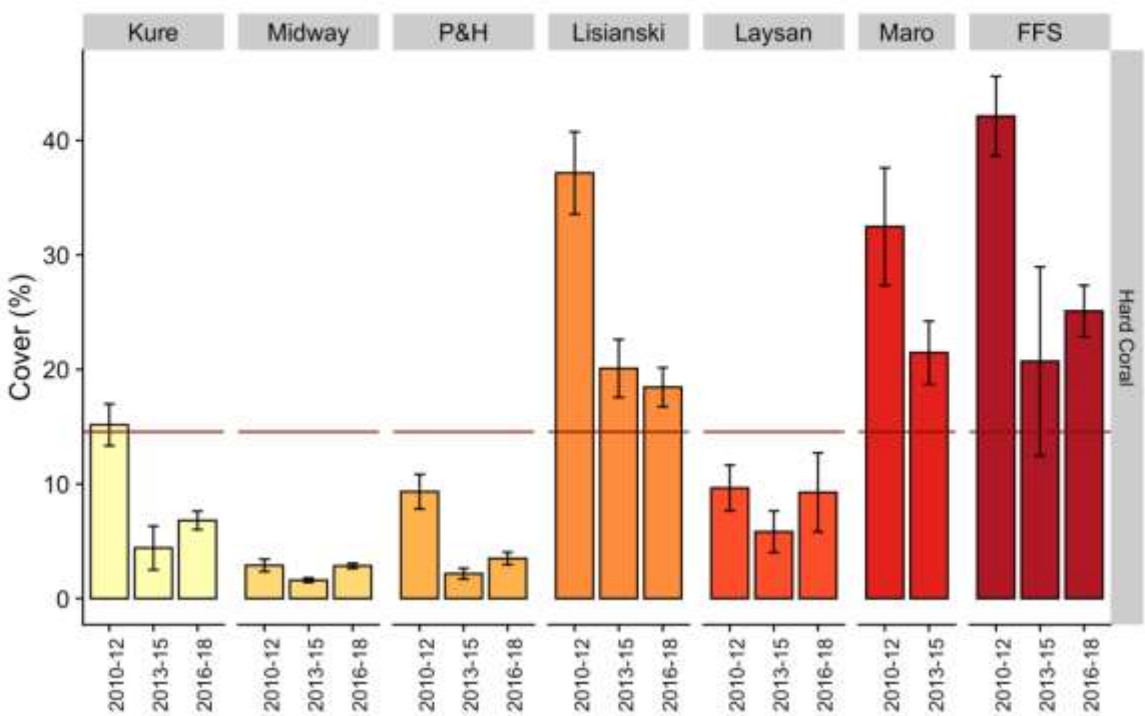

Figure 5. Mean coral cover (%) per island averaged over the years 2010-2019 by latitude with NWHI mean estimates plotted for reference (red line)

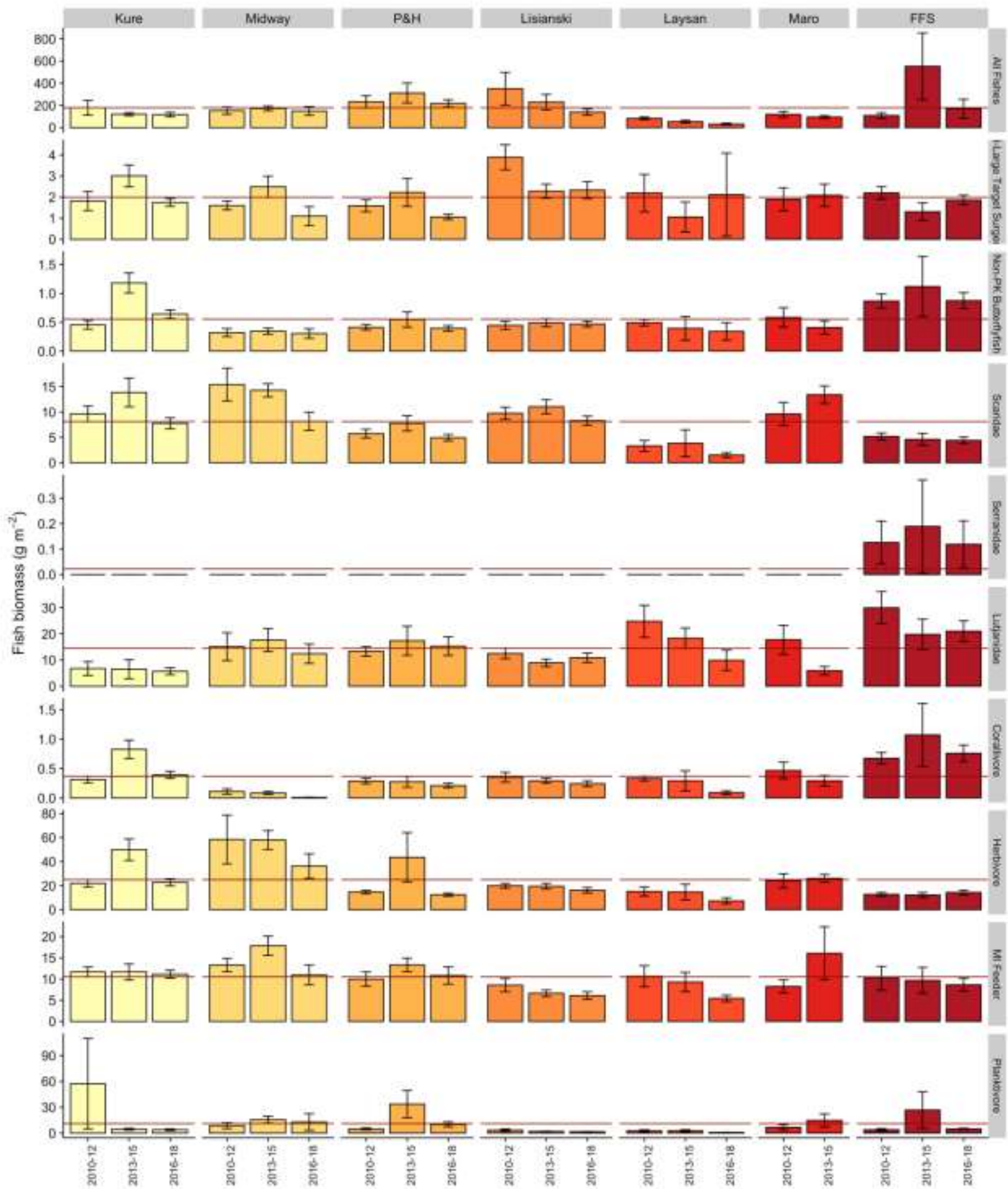

Figure 6. Mean fish biomass (g/m^2 ± standard error) of NWHI functional, taxonomic, and trophic groups from the years 2010-2019 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). The group "MI Feeder" consists of fishes that primarily feed on mobile invertebrates; with NWHI mean estimates plotted for reference (red line)

2.4 LIFE HISTORY AND LENGTH DERIVED PARAMETERS

2.4.1 MHI Coral Reef Ecosystem Components Life History

2.4.1.1 Age, Growth, and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or daily growth increments (DGIs) internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. Fish growth is estimated by fitting the length-at-age data to a von Bertalanffy growth function (VBGF). This function typically uses three coefficients (L_∞, k, and t_0), which together characterize the shape of the length-at-age growth relationship.

Length-at-reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved, cut into five-micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region) - such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes - standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a three or four-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

Data Category: Biological

Timeframe: N/A

Jurisdiction: MHI and NWHI

Spatial Scale: Archipelagic

Data Source: Sources of data are directly derived from research cruises sampling and market samples purchased from local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC Life History Program (LHP). Refer to the "Reference" column in Table 46 for specific details on data sources by species.

Parameter definitions:

T_{max} (maximum age) – The maximum observed age revealed from an otolith-based age determination study. T_{max} values can be derived from ages determined by annuli counts of sagittal otolith sections and/or bomb radiocarbon (^{14}C) analysis of otolith core material. Units are years.

L_∞ (asymptotic length) – One of three coefficients of the VBGF that measures the mean maximum length at which the growth curve plateaus and no longer increases in length with increasing age. This coefficient reflects the estimated mean maximum length and not the observed maximum length. Units are centimeters.

k (growth coefficient) – One of three coefficients of the VBGF that measures the shape and steepness by which the initial portion of the growth function approaches its mean maximum length (L_∞).

t_0 (hypothetical age at length zero) – One of three coefficients of the VBGF whose measure is highly influenced by the other two VBGF coefficients (k and L_∞) and typically assumes a negative value when specimens representing early growth phases) are not available for age determination. This parameter can be fixed at 0. Units are years.

M (natural mortality) – This is a measure of the mortality rate for a fish stock and is considered to be directly related to stock productivity (i.e., high M indicates high productivity and low M indicates low stock productivity). M can be derived through use of various equations that link M to T_{max} and the VBGF coefficients (k and L_∞) or by calculating the value of the slope from a regression fit to a declining catch curve (regression of the natural logarithm of abundance versus age class) derived from fishing an unfished or lightly fished population.

A_{50} (age at 50% maturity) – Age at which 50% of the sampled stock under study has attained reproductive maturity. This parameter is best determined based on studies that concurrently determine both age (otolith-based age data) and reproductive maturity status (logistic function fitted to percent mature by age class with maturity determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating A_{50} is to use an existing L_{50} estimate to find the corresponding age (A_{50}) from an existing VBGF curve. Units are years.

$A\Delta_{50}$ (age of sex switching) – Age at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal. This parameter is best determined based on studies that concurrently determines both age (otolith-based age data) and reproductive sex reversal status (logistic function fitted to percent sex reversal by age class with sex reversal determined via microscopic analyses of gonad histology preparations). A more approximate means of estimating $A\Delta_{50}$ is to use an existing $L\Delta_{50}$ estimate to find the corresponding age ($A\Delta_{50}$) from the VBGF curve. Units are years.

L_{50} (length at which 50% of a fish population are capable of spawning) – Length at which 50% of the females of a sampled stock under study has attained reproductive maturity; this is the length associated with A_{50} estimates. This parameter is derived using a logistic function to fit the percent mature data by length class with maturity status best determined via microscopic analyses of gonad histology preparations. L_{50} information is typically more available than A_{50} since L_{50} estimates do not require knowledge of age and growth. Units are centimeters.

$L\Delta_{50}$ (length of sex switching) – Length at which 50% of the immature and adult females of the sampled stock under study is undergoing or has attained sex reversal; this is the length associated with $A\Delta_{50}$ estimates. This parameter is derived using a logistic function to fit the percent sex reversal data by length class with sex reversal status best determined via microscopic analyses of gonad histology preparations. $L\Delta_{50}$ information is typically more available than $A\Delta_{50}$ since $L\Delta_{50}$ estimates do not require knowledge of age and growth. Units are centimeters.

Rationale: These nine life history parameters provide basic biological information at the species level to evaluate the productivity of a stock - an indication of the capacity of a stock to recover once it has been depleted. Currently, the assessment of coral reef ecosystem resources in Hawaii are data limited. Knowledge of these life history parameters support current efforts to characterize the resilience of these resources and also provide important biological inputs for future stock assessment efforts and enhance our understanding of the species-likely role and status as a component of the overall ecosystem. Furthermore, knowledge of life histories across species at the taxonomic level of families or among different species that are ecologically or functionally similar can provide important information on the diversity of life histories and the extent to which species can be grouped (based on similar life histories) for future multi-species assessments.

Table 46. Available age, growth, and reproductive maturity information for coral reef ecosystem component species in the Hawaiian Archipelago

Species		Age, growth, and reproductive maturity parameters								Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Acanthurus triostegus										
Calotomus carolinus	4[d]					1.3[d]	3.2 [d]	24[d]	37[d]	DeMartini et al. (2017); DeMartini and Howard (2016)
Caranx melampygus										
Cellana spp.										
Chlorurus perspicillatus	19[d]	53.2[d]	0.23[d]	-1.48[d]		3.1[d]	7 [d]	34[d]	46[d]	DeMartini et al. (2017); DeMartini and Howard (2016)
Chlorurus spilurus	11[d]	34.4[d]	0.40[d]	-0.13[d]		1.5[d]	4 [d]	17[d]	27[d]	DeMartini et al. (2017); DeMartini and Howard (2016)
Kyphosus bigibbus										
Lobster										
Lutjanus										

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_∞	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
kasmira										
Naso annulatus										
Octopus cyanea										
Panulirus marginatus[1]		104.33-147.75[d]	0.05-0.58[d]					40.5[d]		O'Malley (2009); DeMartini et al. (2005)
Parupeneus porphyus										
Scaridae										
Scarus psittacus	6[d]	32.7[d]	0.49[d]	-0.01[d]		1[d]	2.4 [d]	14[d]	23[d]	DeMartini et al. (2017); DeMartini and Howard (2016)
Scarus rubroviolaceus	19[d]	53.5[d]	0.41[d]	0.12[d]		2.5[d]	5 [d]	35[d]	47[d]	DeMartini et al. (2017); DeMartini and Howard (2016)
Scyllarides squammosus[2]		X[a]	X[a]					51.1		O'Malley (2009); DeMartini et al. (2005)
Naso unicornis	54[d]	47.8[d]	0.44[d]	-0.12[d]				f=35.5[d] m=30.1[d]		Andrews et al. (2016); DeMartini et al. (2014)

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).
[1] *Panulirus marginatus* growth rates (k and L_∞) are from a range of locations in the NWHI for both sexes.
[2] *Scyllarides squammosus* growth rates available for Schnute growth model but not from von Bertalannfy growth model (i.e., no k or L_∞).

Parameter estimates are for females unless otherwise noted (f=females, m=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_∞, L_{50}, and $L\Delta_{50}$ are in units of mm fork length (FL); k is in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable.

2.4.2 MHI Bottomfish Management Unit Species Life History

2.4.2.1 Age, Growth, and Reproductive Maturity

Description: Age determination is based on counts of yearly growth marks (annuli) and/or DGIs internally visible within transversely cut, thin sections of sagittal otoliths. Validated age determination is based on several methods including an environmental signal (bomb radiocarbon ^{14}C) produced during previous atmospheric thermonuclear testing in the Pacific and incorporated into the core regions of sagittal otolith and other aragonite-based calcified structures such as hermatypic corals. This technique relies on developing a regionally based aged coral core reference series for which the rise, peak, and decline of ^{14}C values is available over the known age series of the coral core. Estimates of fish age are determined by projecting the ^{14}C otolith core values back in time from its capture date to where it intersects with the known age ^{14}C coral reference series. Fish growth is estimated by fitting the length-at-age data to a VBGF. This function typically uses three coefficients (L_∞, k, and t_0), which together characterize the shape of the length-at-age growth relationship.

Length-at-reproductive maturity is based on the histological analyses of small tissue samples of gonad material that are typically collected along with otoliths when a fish is processed for life history studies. The gonad tissue sample is preserved, cut into five micron sections, stained, and sealed onto a glass slide for subsequent examination. Based on standard cell structure features and developmental stages within ovaries and testes, the gender, developmental stage, and maturity status (immature or mature) is determined via microscopic evaluation. The percent of mature samples for a given length interval are assembled for each sex and these data are fitted to a three- or four-parameter logistic function to determine the best fit of these data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish have achieved reproductive maturity (L_{50}). For species that undergo sex reversal (primarily female to male in the tropical Pacific region) - such as groupers and deeper-water emperors among the bottomfishes, and for parrotfish, shallow-water emperors, and wrasses among the coral reef fishes - standard histological criteria are used to determine gender and reproductive developmental stages that indicate the transitioning or completed transition from one sex to another. These data are similarly analyzed using a three or four-parameter logistic function to determine the best fit of the data based on statistical analyses. The mid-point of this fitted function provides an estimate of the length at which 50% of fish of a particular species have or are undergoing sex reversal ($L\Delta_{50}$).

Age at 50% maturity (A_{50}) and age at 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the VBGF for that species and using the corresponding L_{50} and $L\Delta_{50}$ values to obtain the corresponding age value from this growth function. In studies where both age & growth and reproductive maturity are concurrently determined, estimates of A_{50} and $A\Delta_{50}$ are derived directly by fitting the percent of mature samples for each age (one-year) interval to a three- or four-parameter logistic function using statistical analyses. The mid-point of this fitted logistic function provides a direct estimate of the age at which 50% of fish of a particular species have achieved reproductive maturity (A_{50}) and sex reversal ($A\Delta_{50}$).

<u>Data Category</u>: Biological

<u>Timeframe</u>: N/A

<u>Jurisdiction</u>: MHI and NWHI

<u>Spatial Scale</u>: Archipelagic

<u>Data Source</u>: Sources of data are directly derived from research cruises sampling and market samples purchased from local fish vendors. Laboratory analyses and data generated from these analyses reside with the PIFSC LHP. Refer to the "Reference" column in Table 47 for specific details on data sources by species.

<u>Parameter Definitions</u>: Identical to Section 2.4.2.1

Parameter estimates are for females unless otherwise noted (f=females, m=males). Parameters T_{max}, t_0, A_{50}, and $A\Delta_{50}$ are in units of years; L_∞, L_{50}, and $L\Delta_{50}$ are in units of mm FL; k is in units of year^{-1}; X=parameter estimate too preliminary or Y=published age and growth parameter estimates based on DGI numerical integration technique and likely to be inaccurate; NA=not applicable.

Table 47. Available age, growth, reproductive maturity, and natural mortality information for bottomfish MUS in the Hawaiian Archipelago

Species	Age, growth, and reproductive maturity parameters									Reference
	T_{max}	L_{∞}	k	t_0	M	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Aphareus rutilans							NA		NA	
Aprion virescens	27[d]	72.78[d]	0.31[d]		0.24[d]		NA	42.5-47.5[d]	NA	Everson et al. (1989); O'Malley et al. (in press)
Etelis carbunculus	22[c]	50.3[c]	0.07[c]				NA	23.4[d]	NA	Nichols et al. (in review); DeMartini (2016)
Etelis coruscans	f=55[d] m=51[d]	f=87.6[d] m=82.7[d]	f=0.12[d] m=0.13[d]	f=-1.02[d] m=-1.37[d]		X[a]	NA	62.2[d]	NA	Reed et al. (in press); Andrews et al. (2020)
Hyporthodus quernus	76[d]	0.078[d]	95.8[d]					58.0[d]	89.5[d]	Andrews et al. (2019); DeMartini et al. (2010)
Pristipomoides filamentosus	42[d]	67.5[d]	0.24[d]	-0.29[d]			NA	f=40.7[d] m=43.3[d]	NA	Andrews et al. (2012); Luers et al. (2017)
Pristipomoides sieboldii							NA	23.8[d]	NA	DeMartini (2016)
Pristipomoides zonatus							NA		NA	

[a] signifies estimate pending further evaluation in an initiated and ongoing study.
[b] signifies a preliminary estimate taken from ongoing analyses.
[c] signifies an estimate documented in an unpublished report or draft manuscript.
[d] signifies an estimate documented in a finalized report or published journal article (including in press).

2.5 SOCIOECONOMICS

This section outlines the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of Fishery Ecosystem Plan for the Hawaii Archipelago (WPRFMC 2009). It meets the objective "Support Fishing Communities" adopted at the 165th Council meeting; specifically, it identifies the various social and economic groups within the region's fishing communities and their interconnections. The section begins with an overview of the socioeconomic context for the region, and then provides a summary of relevant studies and data for Hawaii, followed by summaries of relevant studies and data for each fishery within the Hawaiian archipelago.

In 1996, the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 8 (NS8) specified that conservation and management measures take into account the importance of fishery resources to fishing communities, to provide for their sustained participation in fisheries and to minimize adverse economic impacts, provided that these considerations do not compromise the achievement of conservation. Unlike other regions of the U.S., the settlement of the Western Pacific region was intimately tied to the sea (Figure 7), which is reflected in local culture, customs, and traditions.

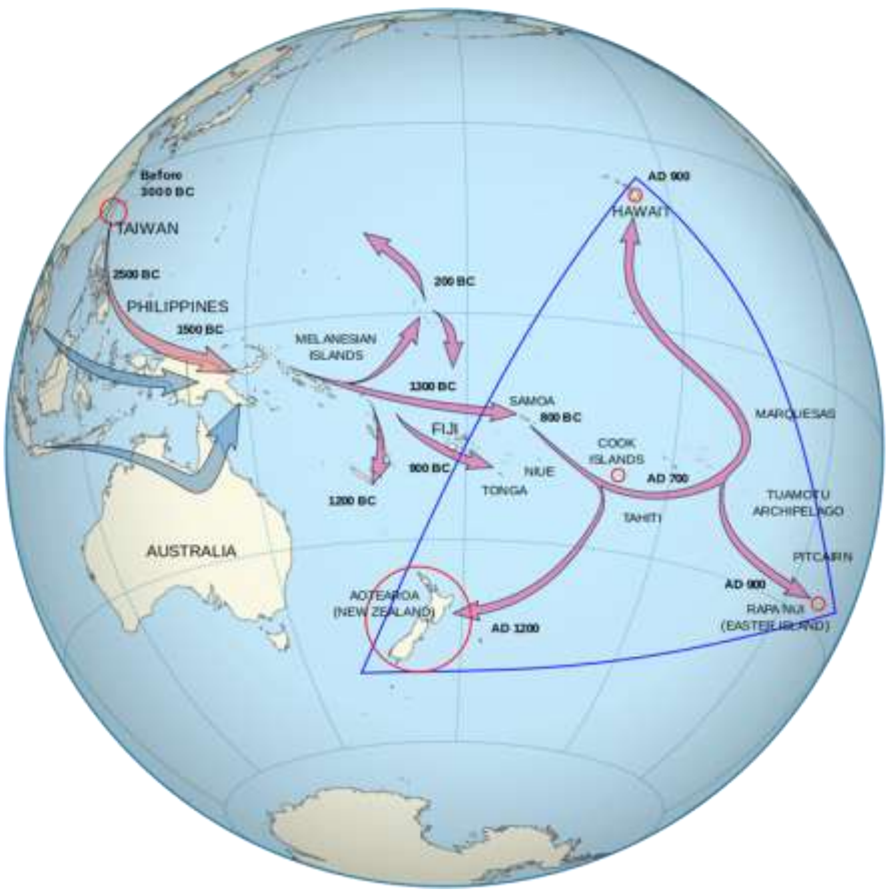

Figure 7. Settlement of the Pacific Islands, courtesy Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg

Polynesian voyagers relied on the ocean and marine resources on their long voyages in search of new islands, as well as in sustaining established island communities. Today, the population of the region also represents many Asian cultures from Pacific Rim countries, which reflect similar importance of marine resources. Thus, fishing and seafood are integral local community ways of life. This is reflected in the amount of seafood eaten in the region in comparison to the rest of the United States, as well as the language, customs, ceremonies, and community events. It can also affect seasonality in prices of fish. Because fishing is such an integral part of the culture, it is difficult to cleanly separate commercial from non-commercial fishing, with most trips involving multiple motivations and multiple uses of the fish caught. While the economic perspective is an important consideration, fishermen report other motivations such as customary exchange as being equally, if not more, important. Due to changing economies and westernization, recruitment of younger fishermen is becoming a concern for the sustainability of fishing and fishing traditions in the region.

2.5.1 Response to Previous Council Recommendations

At its 185th meeting held via web conference in March 2021, the Council directed staff to review and analyze EO 13985 to Advance Racial Equity and Support Underserved Communities through the Federal Government. PIFSC staff are involved in the development of the NOAA strategy and are including concerns from the Pacific Islands Region into the national strategy.

Also at the 185th meeting, the Council directed staff to work with the SSC subgroup to finalize the plan incorporating PIFSC recommendations and the socioeconomic priorities identified by the SSPC in April 2021. These recommendations were included in the revised SSC plan.

At its 186th meeting held via web conference in June 2021, the Council directed the SSPC to work with the Advisory Panels to explore conducting periodic check-ins with the fishing communities to provide information for the fishery observations section of the SAFE report. The AP and SSPC formed a small working group that developed a framework for systematic gathering of fisher observations as part of the regular AP meetings for a new section of the SAFE report. The first set of meetings following this format will be held in 2022.

2.5.2 Introduction

The geography and overall history of the Hawaiian Archipelago, including indigenous culture and current demographics and description of fishing communities is described in the Fishery Ecosystem Plan for the Hawaii Archipelago (WPRFMC 2009). Over the past decade, several studies have synthesized more specifics about the role of fishing and marine resources across the Hawaiian archipelago, as well as information about the people who engaging in the fisheries or use fishery resources.

As described in Chapter 1, a number of studies have outlined the importance of fishing for Hawaiian communities through history (e.g., Geslani et al. 2012; Richmond and Levine 2012). Traditional Native Hawaiian subsistence relied heavily on fishing, trapping shellfish, and collecting seaweed to supplement land-based diets. Native Hawaiians also maintained fishponds, some of which date back thousands of years are still used today. The Native Hawaiian land and marine tenure system, known as ahupuaʻa-based management, divided the islands into large parcels called moku, which are reflected in modern political boundaries (Census County Districts).

Immigrants from many other countries with high seafood consumption and cultural ties to fishing and the ocean came to work on the plantations around the turn of the 20th Century, establishing in Hawaii large populations of Chinese, Japanese, Koreans, Filipinos, and Portuguese, among others. In 1985, the Compact of Free Association also encouraged a large Micronesian population to migrate to Hawaii. According to the 2020 Census, the State of Hawaii's population is almost 1.5 million. Ethnically, it has the highest percentage of Asian Americans (37.2%) and Multiracial Americans (25.3%) and the lowest percentage of White Americans (22.9%) of all states. Approximately 27% of the population identifies as Native Hawaiian or part Native Hawaiian. Tourism from many of these Asian countries also increases the demand for fresh, high-quality seafood, especially sushi, sashimi, and related raw fish products such as poke.

Today, fishing continues to play a central role in the local Hawaiian culture, diet, and economy. In 2012, an estimated 486,000 people were employed in marine-related businesses in Hawaii, with the level of commercial fishing-related employment well above the national average (Richmond et al. 2015). The Fisheries Economics of the United States 2019 report found that the commercial fishing and seafood industry in Hawaii (including the commercial harvest sector, seafood processors and dealers, seafood wholesalers and distributors, importers, and seafood retailers) generated $786 million in sales impacts and approximately 7,693 full and part-time jobs that year (NMFS 2022). It is estimated that recreational anglers took 3.5 million fishing trips, with $400 million in sales impacts and 2,911 full- and part-time jobs were generated by recreational fishing activities in the State during 2019. Similarly, the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Department of the Interior et al. 2011) estimated that 157 thousand people over 16 years old participated in saltwater angling in Hawaii in 2011. They fished approximately 1.9 million days, with an average of 12 days per angler. This study estimated that fishing-related expenditures totaled $203 million, with each angler spending an average of $651 on trip-related costs. These numbers are not significantly different from those reported on the 2006 and 2001 national surveys. Due to changes in data availability NMFS does not currently report recreational angler participation at the State level.

Seafood consumption in Hawai'i is estimated at approximately two to three times higher than the rest of the entire U.S., and Hawai'i consumes more fresh and frozen finfish while shellfish and processed seafood is consumed more across the rest of the country (Geslani et al. 2012; Davidson et al. 2012). In addition, studies have shown that seafood is eaten frequently, at least once a week by most, and at least once a month by almost all respondents (NCRMP 2016). Fresh seafood is the most popular type of seafood purchased, and while most is purchased at markets or restaurants, a sizeable amount is reported as caught by friends, neighbors, or extended family (NCRMP 2016; Davidson et al. 2012).

At the same time, local supply is inadequate to meet the high seafood demand. In 2010, 75% of all seafood consumed in the State of Hawaii was imported from either the U.S. mainland or foreign markets, and the rise in imported fish has influenced the price of local catch (Arita et al. 2011; Hospital et al. 2011). In addition, rising costs of fuel and other expenses have made it more difficult to recover trip costs (Hospital et al. 2011). A majority of commercial fishermen report selling their fish simply to recover these costs, not necessarily to make income (Hospital et al. 2011). Many describe the importance of sharing fish as a part of maintaining relationships within family or other networks as being more important than earning income from fishing (personal communication, Bottomfish Oral History project, in progress).

Pelagic fish play a large role in seafood consumption, with Hawaii residents regularly consuming substantial amounts of fresh bigeye and yellowfin tuna as ‘ahi poke (bite-sized cubes of seasoned raw tuna) and ahi sashimi (sliced raw tuna). ‘Ahi is also a significant part of cultural celebrations, especially during the holiday period from late November (Thanksgiving) through late January to mid-February (Chinese New Year). Changes in bigeye regulations can have far-reaching effects not only on Hawai‘i’s fishing community but also on the general population (Richmond et al. 2015). While most of the fresh tuna consumed in Hawaii is supplied by the local industry, market observations suggest that imported tuna is becoming more commonplace to meet local demands (Pan 2014).

Examination of the seascape of compliance across the US Pacific Island region found, that while the literature highlights the importance of enforcement, local experts emphasized barriers of capacity, governance process, and the lack of data. This suggests that non-instrumental and governance approaches can complement enforcement and should be part of an integrated compliance approach both in the region (Ayers and Leong 2020).

2.5.3 People Who Fish

Hawaii includes a mix of commercial, non-commercial, and subsistence characteristics across fisheries. Archipelagic fisheries are primarily accessed via a small boat fleet and through shoreline fishing. Within the small boat fleet, there is a nearly continuous gradation from the full-time and part-time commercial fleet to the charter and personal recreation fleets. A single boat (and trip) will often utilize multiple gear types and target fish from multiple fisheries. Thus, other than the longline fishery, these fisheries are typically not studied individually. Rather, studies have typically been conducted based on ability to reach potential respondents. Studies have targeted fishermen via State of Hawaii Commercial Marine Licenses (CMLs) (Chan and Pan 2017; Madge et al. 2016), shoreline and boat ramp intercepts (Hospital et al. 2011; Madge et al. 2016), and vessel and angler registries (Madge et al. 2016).

The Hawaii small boat pelagic fleet was studied in 2007-2008 (hereafter, referred to as the 2008 study), following a design last utilized in 1997 (Hospital et al. 2011). Because respondents also targeted insular fish, the study is included in this report. Their work was updated in 2014 by Chan and Pan (2017) for the small boat fleet in general. Both studies found that the small boat fleet is predominantly owner-operated and a male dominated activity (98% of respondents were male in both studies). The ethnic composition was predominantly Asian (45% in 2008, 41% in 2014) and White (23% in 2008, 26% in 2014), which is similar to the demographics of the State population as a whole. In 2014, proportionally more Native Hawaiians and Pacific Islanders responded to the survey than are represented in the general population (18% vs. 10%). In addition, most respondents had a household income above $50,000 (75% in 2008, 69% in 2014).

These studies also asked respondents to classify themselves based on categories ranging from commercial to non-commercial. In 2014, 7% identified as full-time commercial, 51% identified as part-time commercial, 27% identified as recreational expense where they sold some catch to offset fishing expenses, 11% as purely recreational, 3% as subsistence, and 1% as cultural. Different activities were then compared based on self-classification.

As previously mentioned, the Hawaii small boat fishery is a mixed-gear fishery. In 2008, 47% of respondents reported using more than one gear type, predominantly trolling (for pelagic fish) and handline (for bottomfish). In 2014, 65% of respondents reported trolling as their most common gear, 16% indicated bottomfish handline, and 12% stated pelagic handline was their most commonly used gear. Trolling was more commonly used by recreational fishermen whereas pelagic handline and bottomfish gears were more commonly used by commercial fishermen. The 2014 study also asked about species composition of catch. While 93% of the respondents reporting landing pelagic fish in the past year, about half of respondents also reported they caught and landed bottomfish or reef fish. Thus, the small boat fleet includes not only a mixture of gear types, but also targets both pelagic and insular fish stocks.

Both studies also examined how fishermen self-identified versus their commercial and non-commercial activities. In both cases, many people who considered themselves recreational, subsistence, or cultural fishers still sold fish. In 2008, 42% of fishermen self-classified as commercial fishermen, yet 60% of respondents reported selling fish in the past year. In addition, just over 30% of fishermen who self-classified as recreational reported selling fish in the past year. Results for the 2014 study are shown in Table 48.

Table 48. Catch disposition by fisherman self-classification (from Chan and Pan 2017)

	Number of respondents (n)	Caught and released (%)	Given away (%)	Consumed at home (%)	Sold (%)
All Respondents	738	5.6	13.9	15.4	65.0
By Fisherman Classification:					
Full-time commercial	*55*	6.2	9.4	11.6	72.8
Part-time commercial	*369*	5.2	12.9	14.4	67.5
Recreational expense	*200*	6.7	19.8	21.7	51.8
Purely recreational	*78*	5.4	37.3	29.6	27.6
Subsistence	*24*	1.9	20.7	31.0	46.5
Cultural	*8*	4.0	36.8	22.5	36.7

In 2014, the average value of fish sold by all respondents was approximately $8,500. Full-time commercial fishermen reported the highest value of fish sold ($35,528 annually and $558 per trip), part-time commercial fishermen reported $8,391 annually and $245 per trip, cultural fishermen $3,900 annually and $150 per trip, recreational expenses fishermen $2,690 annually and $95 per trip, subsistence fishermen $1,905 annually and $79 per trip, and purely recreational fishermen reported selling close to $1,000 annually ($58 per trip). While income from fish selling served as an important source of personal income for full-time commercial fishermen, the majority of fishermen reported selling fish to cover trip expenses, not necessarily to make a profit; few fishermen reported substantial, if any, profits from fishing. In the 2008 study, respondents expressed concern about their ability to cover trip costs, noting that trip costs continued to increase from year to year, but fish prices remained relatively flat.

The 2008 study was also the first attempt to quantify the scale of unsold fish that was shared within community networks. For commercial fishermen, trips where no fish are sold (30.5%) were nearly equal to trips where profit was made (30.9%). In addition, 97% of survey respondents indicated they participated in fish sharing networks with friends and relatives, and more than 62% considered the fish they catch as an important food source for their family. Community networks were also present in the outlets where fish were sold, which included the United Fishing Agency (UFA) auction in Honolulu, dealers/wholesalers, markets/stores, restaurants, roadside, but also sales to friends, neighbors, and coworkers. The 2014 study also documented 27% of sales to friends, neighbors, or coworkers and corroborated the importance of giving away fish for all self-classification categories (Table 48). In addition, 17% of respondents (who all held CMLs) sold no fish in the past 12 months.

Taken together, the results from these studies suggest a disconnect between Hawaii fishermen's attitudes and perceptions of their fishing activity relative to current regulatory frameworks. The small boat fleet is extremely heterogeneous with respect to gear type, target species, and catch disposition, while regulations attempt to treat each separately with clear distinctions between commercial and recreational activities. In addition to providing income, the Hawaii small boat fleet serves many vital nonmarket functions, including building social and community networks, perpetuating fishing traditions, and providing fish to local communities.

A survey was also conducted on the attitudes and preferences of Hawaii non-commercial fishers (see Madge et al. 2016). Nearly all survey respondents were male (96%). Their average age was 53, and, on average, they had engaged in non-commercial saltwater fishing in Hawaii for 31 years. The majority had household income equal to or greater than $60,000, reported high levels of education, and reflected a large racial diversity (primarily various Asian ethnicities and White). They primarily fished via private motorboat (61%), followed by shore, including beach, pier, and bridge (38%). Offshore trolling and whipping/casting, and free-dive spearfishing were the most frequent gears reported as "always" used, and a majority of respondents reported using multiple gears on a single fishing trip.

As with the small boat fleet, even though this study targeted "non-commercial fishermen", 9% reported that their primary motivation for fishing was to sell some catch to recover trip expenses. However, the primary motivation for the majority (51%) was purely for recreational purposes (only for sport or pleasure). A total of 78% of respondents indicated they "always" or "often" share catch with family and friends, and only 35% indicated they "never" supply fish for community/cultural events. Fishing for home/personal consumption was the most important trip catch outcome (36% rated it "extremely important"), followed by catching enough fish to be able to share with friends and family (20%). 36% indicated that their catch was extremely or very important to their regular diet. Thus, similar to the small boat fleet, non-commercial fishermen demonstrate mixed motivations that include commercial activities. They also play an important role in providing fish via social and community networks, even though they report their primary motivation as fishing only for sport or pleasure.

NMFS and the Hawaiʻi DAR have been collecting information on recreational fishing in Hawaiʻi, administered through the Hawaiʻi Marine Recreational Fishing Survey (HMRFS; Allen and Bartlett 2008; Ma and Ogawa 2016). The program collected data from 1979-1981, but not from 1982-2000, and then began annual data collection again in 2001. A dual survey approach is currently used. A telephone survey of a random sample of households determines how many have done any fishing in the ocean, their mode of fishing, methods used, and effort. The telephone survey component will be discontinued after 2017 due to declining land line coverage. Concurrently, surveyors conduct in-person intercept surveys at boat launch ramps, small boat harbors, and shoreline fishing sites. Fisher County of residence and zip code is regularly collected in the intercept surveys but has not yet been compared to the composition of the general public. As with the other surveys, this program documented a mix of gears used to catch both pelagic and insular fish. The majority of trips monitored by the on-site interviews were from "pure recreational fishermen", defined as those who do not sell their catch, with an average of nearly 60% to over 80% depending on year and island. However, they also noted that the divisions between commercial, non-commercial, and recreational are not clearly defined in

Hawaii, and results suggested that the majority of catch for some categories of fishermen may be consumed by themselves or given away.

2.5.3.1 Bottomfish

This section reviews important community contributions of the MHI bottomfish fishery (Hospital and Pan 2009; Hospital and Beavers 2011; Hospital and Beavers 2012; Chan and Pan 2017) For studies that examined the small boat fishery in general (Hospital et al. 2011; Chan and Pan 2017), overall fisher demographics and catch disposition were summarized in Chapter 1, as bottomfish fishing is only one of the gear types used by the small boat fleet.

Economically, the MHI bottomfish fishery is much smaller scale than the large pelagic fisheries in the region, but it is comparable in terms of rich tradition and cultural significance. Bottomfish fishing was part of the culture and economy of Native Hawaiians long before European explorers ever visited the region. Native Hawaiians harvested the same species as the modern fishery, and much of the gear and techniques used today are modeled after those used by Native Hawaiians. Most of the bottomfish harvested in Hawaii are red, which is considered an auspicious color in many Asian cultures, symbolic of good luck, happiness, and prosperity. Whole red fish are sought during the winter holiday season to bring good luck for the New Year from start to finish, and for other celebrations, such as birthdays, graduations, and weddings. Many restaurants across the State of Hawaii also serve fresh bottomfish, which are sought by tourists.

The bottomfish fishery grew steadily through the 1970s and into the 1980s but experienced steady declines in the following decades. Much of the decline in domestic production has been attributed to the limited-entry management regime introduced in the early 1990s in the NWHI and reductions in fishing vessels and trips fleet-wide. In the late 1990s, research identified overfishing as a contributor to the declines, which led to establishment of spatial closure areas (bottomfish restricted fishing areas [BRFAs]), a bottomfish boat registry, and a noncommercial bag limit for Deep 7 species. Emergency closures in 2007 also resulted in today's Total Allowable Catch (TAC) management regime, which sets a quota for the MHI Deep 7 bottomfish. Under this system, commercial catch reports are used to determine when the quota has been reached for the season, at which point both the commercial and non-commercial fisheries remain closed. This has implications for the ability of fishermen to build and maintain social and community networks throughout the year, given the cultural significance of this fishery.

In addition, in June 2006 the Northwestern Hawaiian Islands Marine National Monument was established in the NWHI, prohibiting all extractive activity and phasing out the active NWHI bottomfish fishery. This removed a source of approximately 35% of domestic bottomfish from Hawaii markets. The market has increasingly relied on imports to meet market demands, which may affect the fishery's traditional demand and supply relationships.

Overall, 45% of the MHI small boat fleet participated in the bottomfish fishery when last surveyed in 2014 (Chan and Pan 2017). The MHI bottomfish fleet is a complex mix of commercial, recreational, cultural, and subsistence fishing. The artisanal fishing behavior, cultural motivations for fishing and relative ease of market access do not align well with mainland U.S. legal and regulatory frameworks.

In a 2010 survey, bottomfish fishermen were asked to define what commercial fishing meant to them (Hospital and Beavers 2012). The majority of respondents agreed that selling fish for profit, earning a majority of income from fishing, and relying solely on fishing to provide income all constituted commercial fishing. However, there was less agreement on other legally established definitions, such as selling one fish, selling a portion of fish to cover trip expenses, the trade and barter of fish, or selling fish to friends and neighbors. In the 2014 survey (Chan and Pan 2017), fishers whose most common gear was bottomfish handline identified themselves as primarily part-time commercial fishermen (53% selected this category) and recreational expense fishermen (21%). Only a few self-identified as full-time commercial (11%), purely recreational (9%), subsistence (6%) or cultural (1%) fishermen. Overall, bottomfish represented a lower percentage of total catch (11%) than total value (23%). While fishery highliners appear to be able to regularly recover trip expenditures and make a profit from bottomfish fishing trips, they represented only 8% of those surveyed in 2014. It is clear that for a majority of participants that the social and cultural motivations for bottomfish fishing outweigh economic prospects.

2.5.3.2 Reef Fish

As described in the reef fish fishery profile (Markrich and Hawkins 2016), coral reef species have been shown by the archaeological record to be part of the customary diet of the earliest human inhabitants of the Hawaiian Islands, including the NWHI. Coral reef species also played an important role in religious beliefs and practices, extending their cultural significance beyond their value as a dietary staple. For example, some coral reef species are venerated as personal, family, or professional gods called ‘aumakua. While the majority of the commercial catch comes from nearshore reef areas around the MHI, harvests of some coral reef species also occur in federal waters (e.g., around Penguin Bank).

From 2014-2015, the National Coral Reef Monitoring Program conducted a household telephone survey of adult residents in the MHI to better understand demographics in coral reef areas, human use of coral reef resources, and knowledge, attitudes, and perceptions of coral reefs and coral reef management. This section summarizes results of the survey, which are available as an online presentation[4].

Just over 40% of respondents participated in fishing, while almost 60% had never participated. However, almost all respondents reported recreational use of coral reef resources, including swimming or wading (80.9%), beach recreation (80.2%), snorkeling (just under 60%), waterside or beach camping (just over 50%), and wave riding (over 40%). Gathering of marine resources was the least frequently reported, with only about 25% participating in this specific activity.

Of those who fished or harvested marine resources, the reason with the highest level of participation was “to feed myself and my family/household” (80.2%). The reason with the lowest level of participation was “to sell” (82.5% never participate). Other reasons with over 60% each were: for fun, to give extended family members and/or friends, and for special occasions and cultural purposes/events. This indicates a substantial contribution from this fishery to local food security, as well as maintaining cultural connections.

The importance of culture was also evident in perceptions of value related to coral reefs. The statement that respondents agreed the most with was “Coral Reefs are important to Hawaiian culture” (93.8%). They also agreed strongly that healthy coral reefs attract tourists to the Hawaiian Islands and that coral reefs protect the Hawaiian Islands from erosion and natural

[4] Presentation is available at:
https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/monitoring/SocioEconomic/NCRMPSOCHawaiiReportOut2016_FINAL_061616_update.pdf

disasters. The statement that respondents disagreed with the most was "coral reefs are only important to fisherman, divers, and snorkelers" (76.2%).

With respect to management strategies, at least half of respondents agreed with all the presented management strategies, which ranged from catch limits, to gear restrictions, to enforcement, and no take zones. Respondents disagreed most with "establishment of a non-commercial fishing license" (27.2%) and "limited use for recreational activities" (25.2%).

Just over half of the respondents (55%) perceive their local communities as at least moderately involved in protecting and managing coral reefs. However, only about a quarter (26%) of respondents indicated moderate or higher involvement themselves.

The importance of protecting and managing coral reefs was also identified in a 2007 study on spearfishing in Hawaii (Stoffle and Allen 2012). Spearfishing was not seen as just a sport but a vehicle for learning the appropriate ways to interact with and protect the environment, including how to carry oneself as a responsible fisherman. For many, learning to spearfish was an important part of "who you are" growing up near the ocean. Fishing also was discussed as a means of providing food or extra income during times of hardship, describing the ocean as a place that people turn to in times of economic crisis. Although there is a growing segment of people who spearfish for sport, with motivations focused more on the experience of the hunt, physical activity, and the sense of achievement. Like other methods of fishing, motivations for spearfishing often cross commercial, recreational, and subsistence lines, including sharing catch with family and among cultural networks.

Overall, coral reef fish not only have a long history of cultural significance in this archipelago, but they also continue to play an important role in subsistence as well as in strengthening social networks and maintaining cultural ties.

2.5.3.3 Crustaceans

There is currently no socioeconomic information specific to the crustacean fishery. Subsequent reports will include new data as resources allow.

2.5.3.4 Precious Corals

There is currently no socioeconomics information specific to precious coral fishery. Subsequent reports will include data as resources allow.

2.5.4 Fishery Economic Performance

2.5.4.1 Costs of Fishing

Past research has documented the costs of fishing in Hawaii (Hamilton and Huffman 1997; Hospital et al. 2011; Hospital and Beavers 2012). This section presents the most recent estimates of trip-level costs of fishing for boat-based bottomfish and coral reef fishing trips in Hawaii. Fishing trip costs were collected from the 2014 Hawaii small boat survey (Chan and Pan 2017) and updated in 2021. Fishermen were asked their fishing trip costs for the most common and second most common gear types they used in the past 12 months and the survey provides information on the variable costs incurred during the operation of vessel including boat fuel, truck fuel, oil, ice, bait, food and beverage, daily maintenance and repair, and other. Table 49 provides estimates for the cost of an average boat-based trips for the four most common trips from the survey conducted in 2014 and 2021 respectively. Estimates for annual fishing expenditures (fixed costs) and levels of investment in the fishery are also provided in the literature.

Table 49. Bottomfish and reef fish trip costs for small boats in Hawaii in **2014 and 2021**

Trip type	Average trip costs from 2014 survey	Average trip costs from 2021 survey
Trolling	294	304
Handling for pelagic	283	304
Handling for bottomfish	253	258
Spearfishing	158	222

Data source: Pacific Islands Fisheries Science Center, https://inport.nmfs.noaa.gov/inport/item/29820 for 2014 survey & https://www.fisheries.noaa.gov/science-blog/hawaii-small-boat-survey-2021-summary for 2021 survey.

2.5.4.2 Commercial Participations, Landings, Revenues, Prices

Designated by the fishery management council and local fishery management agencies in 2019, the management unit species for the Hawaii archipelago include deep 7 bottomfish, uku, and three species of crustaceans (Kona crab and two shrimp, *H. laevigatus* and *ensifer*). All other non-pelagic species and non-MUS are considered as ecosystem component species (ECS). This section will describe trends in commercial participation, landings, revenues, and prices for MUS and ECS, respectively.

2.5.4.2.1 MUS Commercial Participation, Landings, Revenues, Prices

Figure 8 shows the revenue structure of the three species groups (deep 7 bottomfish, uku, and three species of crustaceans) in the MUS. Deep 7 bottomfish are the main component of the MUS. In 2021, total revenue was nearly $1.5 million from the three species groups. Total commercial landings and revenue in 2021 increased 4% and 15%, respectively, compared to 2020. Deep 7 species composed 77% of total revenue, uku was 21%, and crustaceans 2%. On average, during the past 10 years, Deep 7 composed 76% of the total revenue of MUS. Figure 9 shows the number of fishers with MUS sales in 2012-2021. The number of fishers (CML from the HDAR fisher reports) with MUS landings and the number of fishers with MUS sales (CML from the HDAR dealer reports) has decreased since 2014. MUS revenue and commercial landings went down significantly in 2020, while both were up in 2021 but still lower than 2019 levels. In general, the percentage of fishers reporting MUS sales relative to the fishers reporting MUS landings has increased since 2013 but declined in 2020 and 2021. In 2021, the number of fishers (CML) reporting MUS sales slightly dropped 15 fishers from 362 to 347, compared to 2020, while the number of fishers (CML) with MUS landings declined by 19 fishers.

Figure 10 shows the pounds sold and revenue of Deep 7 from 2012 to 2021. Commercial landings of Deep 7 peaked in 2015 and has decreased in recent years. Deep 7 revenues show similar trends to commercial landings. Deep 7 revenues declined 23% in 2020 compared with 2019, while the average annual decrease during the period of 2016-2020 was 11%. The combination of lower prices and lower commercial landings, probably due to impacts associated with pandemic restrictions, resulted in the historical low revenue in 2020. In 2021, Deep 7 revenue went up compared to 2020, while total commercial landings were lower than 2020. The increase of BMUS price in 2021 contributed to the increase in Deep 7 revenue in 2021.

Supporting data for Figure 8, Figure 9, and Figure 10 are presented in Table 50. Please note that the commercial data (the number of fishers/CML with MUS sold, pounds sold, and revenue) were sourced from the HDAR dealer data, while the total participation and landings were sourced from the HDAR fishers report. Figure 16 presents the fish price trends of Deep 7 and uku between 2012 and 2021. Both Deep 7 and uku prices went up in 2021, and Deep-7 price approximated 2019 levels, from $7.50 per pound (adj.) in 2020 to $8.36 per pound in 2021. Uku price in 2021 went up to $5.98 per pound, a historical high. Supporting data for Figure 16 are presented in Table 51.

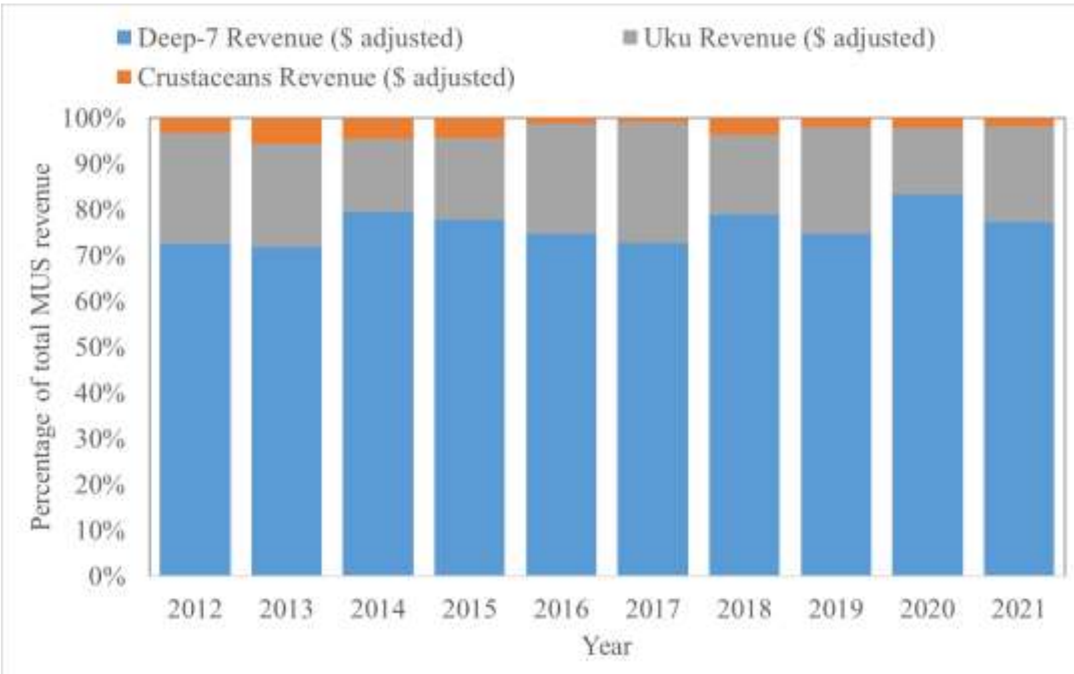

Figure 8. The revenue structure of the three species groups in the MUS, 2012-2021

Table 50. Total participants and revenue structure of the three species groups in the MUS

Year	MUS Pounds kept (lb)	MUS pounds sold (lb)	% of pounds sold	Total CML #	CML # reported with sale	MUS Rev ($)	MUS Rev adj ($)	% Deep-7 of total sold rev	% Uku of total sold rev	% Crustaceans of total sold rev
2012	364,471	300,405	82%	708	522	1,731,964	2,061,037	72%	24%	3%
2013	387,293	316,339	82%	690	528	1,908,276	2,230,775	72%	23%	6%
2014	459,020	369,337	80%	648	517	2,276,827	2,622,905	79%	16%	5%
2015	440,605	383,238	87%	668	533	2,399,708	2,738,067	78%	18%	4%
2016	397,289	360,657	91%	581	484	2,332,979	2,610,604	75%	24%	1%
2017	379,375	349,290	92%	529	462	2,271,009	2,477,671	73%	27%	1%
2018	325,921	291,138	89%	496	419	2,110,269	2,260,098	79%	18%	4%
2019	289,569	250,814	87%	478	403	1,791,227	1,887,953	75%	23%	2%
2020	223,007	183,537	82%	473	362	1,238,594	1,285,661	83%	15%	2%
2021	233,248	191,318	82%	454	347	1,475,057	1,475,057	77%	21%	2%

Data source: PIFSC FRMD from HDAR data.

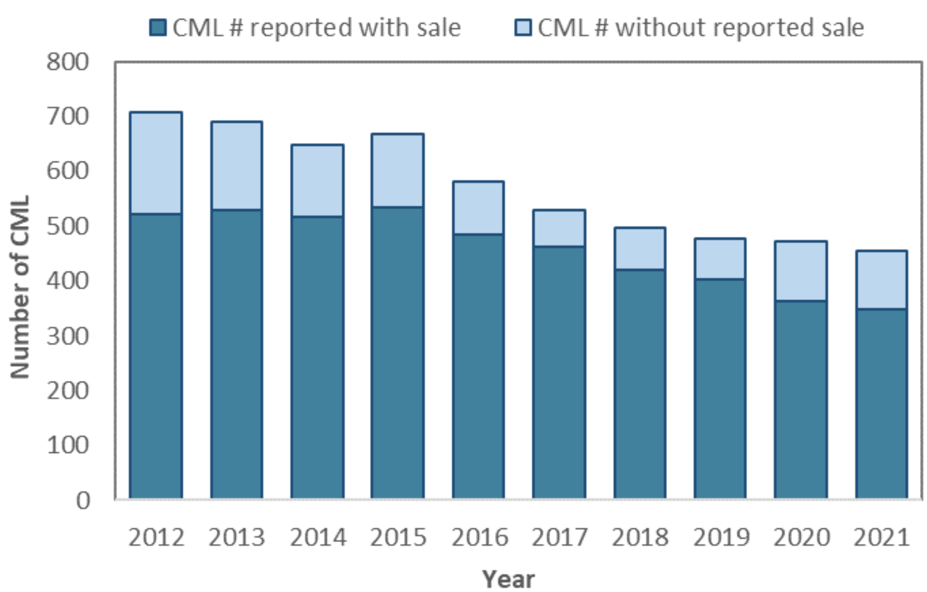

Figure 9. Total fishers in Hawaii MUS, 2012-2021

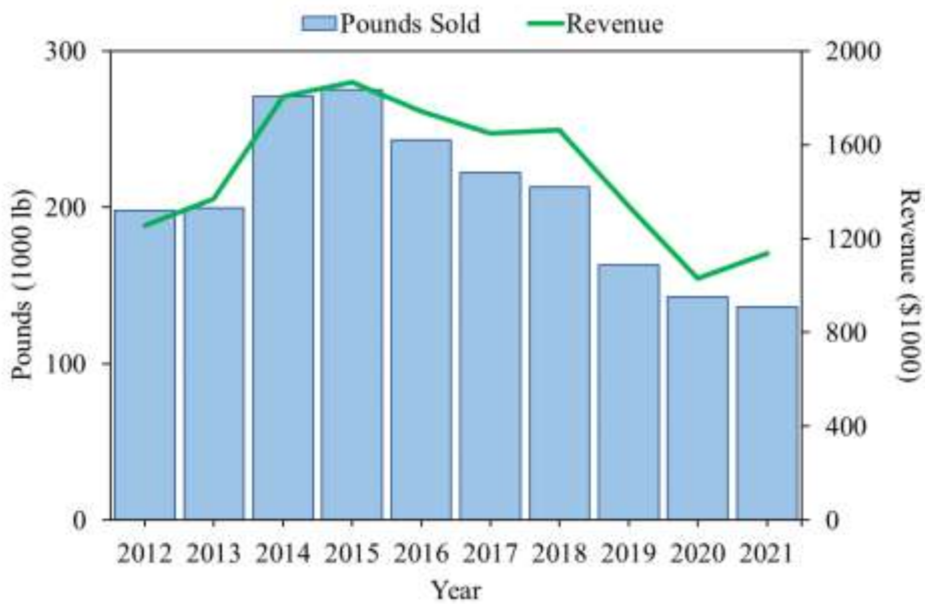

Figure 10. Pounds sold and revenue of Deep 7 Bottomfish, 2012-2021, adjusted to 2021 dollars

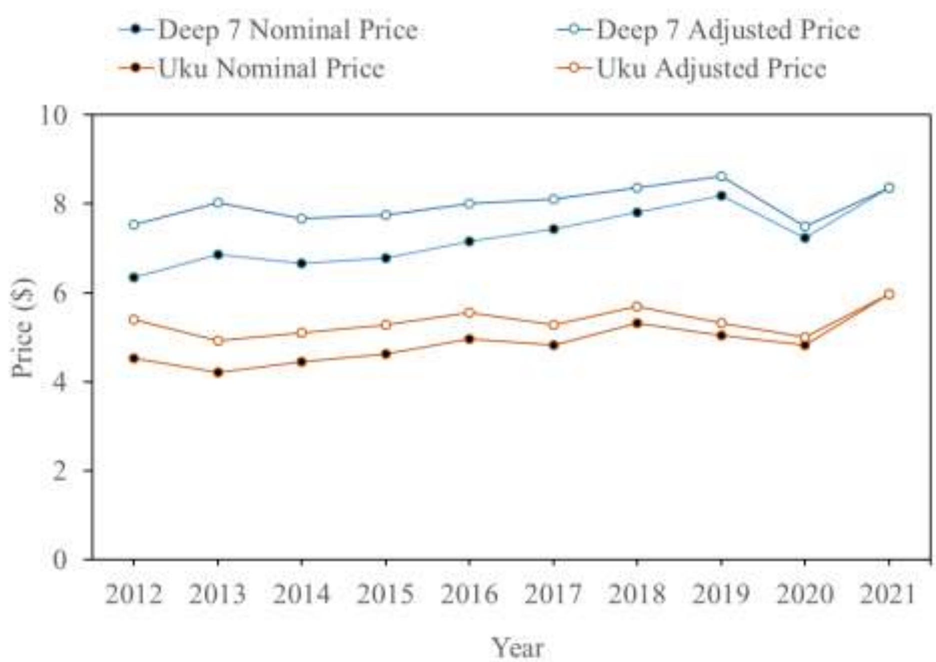

Figure 11. Fish prices for Deep 7 Bottomfish and Uku, 2012-2021

Table 51. Fish sold, revenue, and price information of MUS, 2012-2021

Year	Total pounds sold	Deep-7 pounds sold (lb)	Deep 7 revenue adj ($)	Deep-7 price ($/lb)	Deep-7 price adj. ($/lb)	Uku pounds sold	Uku pounds rev adj ($)	Uku price ($/lb)	Uku price adj. ($/lb)	Crustacean pounds sold	Crustacean rev adj.	Crustacean price ($/lb)	Crustacean price adj ($/lb)	CPI adjustor
2012	300,405	197,766	1,492,456	6.34	7.54	92,831	500,036	4.53	5.39	9,808	68,545	5.87	6.99	1.19
2013	316,339	199,747	1,601,910	6.86	8.02	102,079	503,269	4.22	4.93	14,513	125,596	7.40	8.65	1.169
2014	369,337	270,684	2,080,406	6.67	7.68	82,571	422,695	4.44	5.11	16,082	119,803	6.47	7.45	1.152
2015	383,238	275,262	2,131,328	6.79	7.75	92,063	485,279	4.62	5.27	15,913	121,462	6.69	7.63	1.141
2016	360,657	243,103	1,947,487	7.16	8.01	113,662	631,165	4.96	5.55	3,892	31,951	7.34	8.21	1.119
2017	349,290	221,988	1,798,497	7.43	8.11	124,762	657,781	4.83	5.27	2,541	21,393	7.72	8.42	1.091
2018	291,138	213,157	1,782,235	7.81	8.36	69,495	395,814	5.32	5.70	8,487	82,048	9.03	9.67	1.071
2019	250,814	163,341	1,410,563	8.19	8.63	82,756	440,512	5.05	5.32	4,717	36,878	7.42	7.82	1.054
2020	183,537	142,486	1,070,006	7.23	7.50	37,530	187,843	4.82	5.00	3,521	27,813	7.61	7.90	1.038
2021	191,318	136,062	1,137,655	8.36	8.36	52,087	311,521	5.98	5.98	3,169	25,881	8.17	8.17	1

Data source: PIFSC FRMD from HDAR data. Inflation-adjusted use the Honolulu Consumer Price Index https://www.bls.gov/regions/west/data/consumerpriceindex_honolulu_table.pdf.

2.5.4.2.2 Deep 7 Bottomfish Economic Performance Metrics

NOAA Fisheries has established a national set of economic performance indicators to monitor the economic health of the nation's fisheries (Brinson et al. 2015). PIFSC economists have used this framework to evaluate select regional fisheries; specifically, the Hawaii Longline, American Samoa Longline, and Main Hawaiian Islands (MHI) Deep 7 bottomfish fishery. These indicators include metrics related to catch, effort, and revenues. This section will present revenue performance metrics of; (a) total fishery revenues, (b) fishery revenue per trip, (c) Gini coefficient, and (d) the share of Deep 7 as a percentage of total revenues for the MHI Deep 7 bottomfish fishery.

Revenue per vessel, revenue per trip, and Gini coefficients for the MHI Deep 7 bottomfish fishery include any trip that catches one or more of the Deep 7 bottomfish species in the Main Hawaiian Islands including onaga, ehu, ʻōpakapaka, kalekale, gindai, lehi, and hapuʻupuʻu. The Gini coefficient measures the equality of the distribution of revenue among active vessels in the fishery. A value of zero represents a perfectly equal distribution of revenue amongst these vessels, whereas a value of one represents a perfectly unequal distribution, in the case that a single vessel earns all of the revenue.

The annual total revenue for the MHI Deep 7 bottomfish fishery was estimated based on:

1. The total number of fish kept by species from all MHI Deep 7 fishing trips in a fishing year, as reported by fishermen (including Deep 7 species, non-Deep 7 Bottomfish-Management-Unit-Species (BMUS), and all other species (e.g., pelagic).
2. Fishing years between 2002 and 2006 are defined by calendar year. Since 2007, the fishing year for the MHI Deep 7 bottomfish fishery starts September 1 and ends August 31 of the following year, or earlier if the quota is reached before the end of the season.
3. The weight of the kept catch is estimated as the number of fish kept times the annual average whole weight per fish based on State of Hawaii marine dealer data.
4. The estimated value of the catch is estimated as the weight of the kept catch times the annual average price per pound. This measure assumes all fish landed are sold. Thus, the estimated value would be different from the sale value generated from the dealer's sale value.

For the MHI Deep 7 bottomfish fishery, revenue was calculated by license (CML) because individual revenues are monitored by CML. Multiple fishermen can fish in the same vessel but report their revenue separately, by individual CML. Additionally, a fisherman may fish in different vessels through the year, so revenue is more attached to CML than to vessel and the Gini coefficient essentially measures the equality of the distribution of revenue among active fishermen (CML holders). Gini coefficient 0 indicates “no different” and 1 is “extremely different”. Therefore, the high Gini coefficient in this fishery would imply that a small portion of fishermen account for a large share of fishery revenues. Past research demonstrates evidence of this as participants in this fishery reflect a wide range of motivations and avidity, and there is a relatively small segment of full-time commercial fishery highliners (Hospital and Beavers 2012; Chan and Pan 2017).

Trends in fishery revenues per vessel and the distribution of these revenues across vessels (GINI coefficients) are shown in Figure 12, and the trends in revenue per trip with showing Deep 7 and non-deep 7 revenues, respectively, in Figure 13. In Figure 12, “fishery revenues” refers to Deep 7 bottomfish species catch as well as revenues of other species (such as non-Deep 7 bottomfish, pelagic, and other species) caught on the same Deep 7 fishing trips. As showed in Figure 12, the average Gini coefficient in the past ten years had been steady, 0.75 on average, and it was 0.78 in in 2021, indicating the variations of annual revenue among vessels were substantial. In 2021, the average annual revenue per vessel (CML) from all bottomfish trips was $5,548, dropped $541 from 2020.

In Figure 13, the revenue per trip included Deep-7, non-Deep-7 bottomfish species, and non-bottomfish species (such as pelagic) that were caught in the same trip. Supporting data for Figure 12 and Figure 18 are provided in Table 52.

In 2021 the average annual revenue per a fishing trip from all fish sold was $861, $243 lower than 2020. As Figure 12 shows, the revenue per trip increased from 2011 to 2016 gradually and it tended to stable in recent years since 2016. However, the share of Deep-7 in the trip revenue has shown a downward trend in general, particularly in both 2020 and 2021. On average of the past 10 years, the share of Deep-7 revenue was 74% to the total trip revenue, but it was 60% in 2020 and 67% in 2021, respectively.

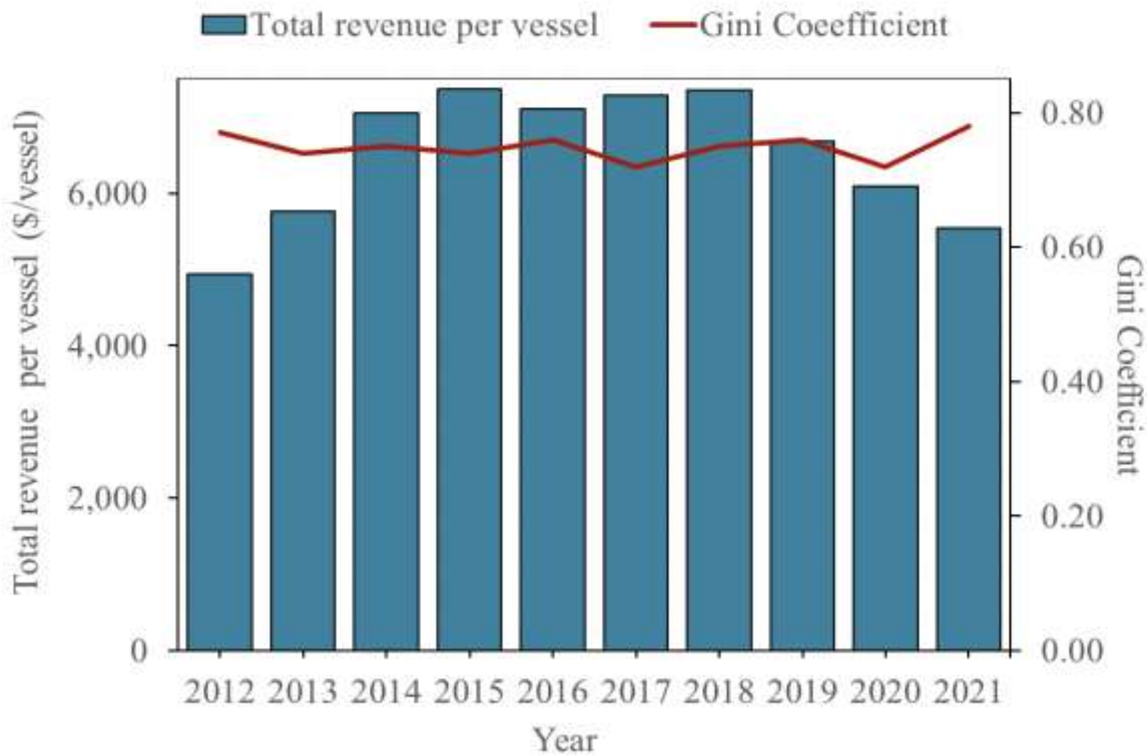

Figure 12. Trends in fishery revenue per vessel and Gini coefficient for the MHI Deep 7 Bottomfish fishery, 2012-2021

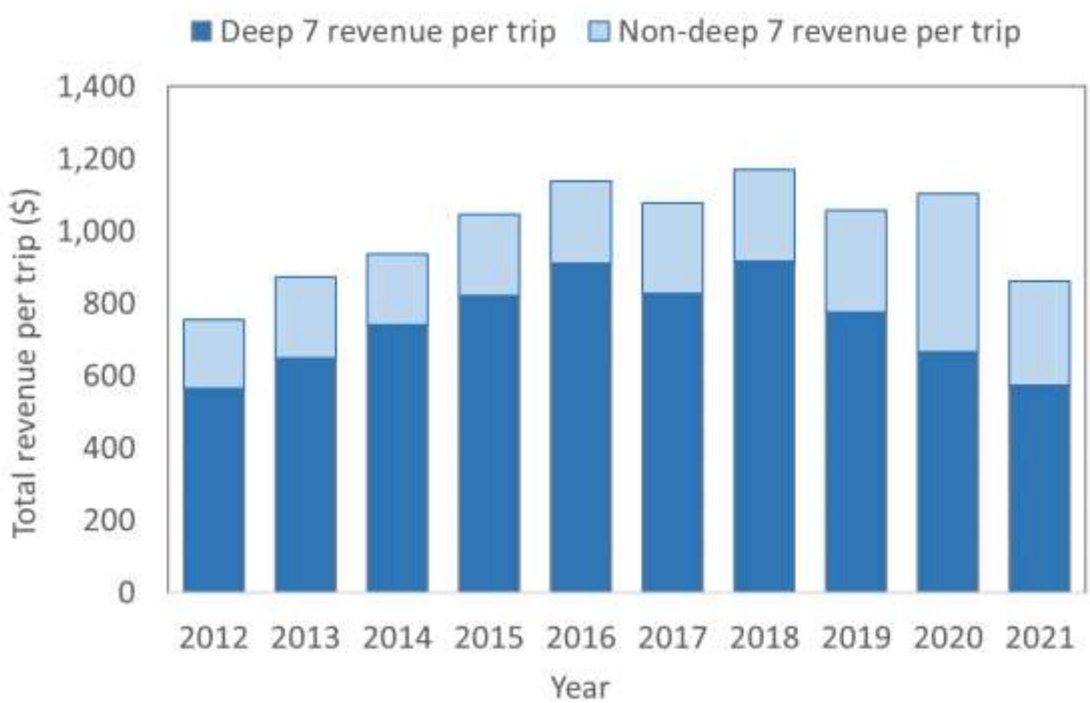

Figure 13. Trends in fishery revenue per trip for Deep 7 and non-deep 7 from bottomfish fishing trips (20121-2021)

Table 52. MHI Deep 7 bottomfish fishery economic performance measures, 2012-2021

Year	Total revenue per vessel ($)	Total revenue per vessel adj. ($)	Gini Coeefficient	Deep-7 revenue per trip ($)	Deep-7 revenue per trip adj. ($)	Non-deep 7 revenue per trip ($)	Non-deep 7 revenue per trip adj. ($)	Total bottomfish revenue per trip ($, adj.)	% of deep-7 in trip revenue	CPI adjustor
2012	4,153	4,942	0.77	475	565	160	190	756	75%	1.190
2013	4,926	5,759	0.74	554	647	194	227	874	74%	1.169
2014	6,117	7,047	0.75	642	739	171	198	937	79%	1.152
2015	6,456	7,366	0.74	720	822	197	225	1,046	79%	1.141
2016	6,353	7,109	0.76	812	909	205	230	1,139	80%	1.119
2017	6,680	7,287	0.72	757	826	232	253	1,079	77%	1.091
2018	6,866	7,354	0.75	855	915	238	255	1,171	78%	1.071
2019	6,343	6,685	0.76	736	776	268	282	1,059	73%	1.054
2020	5,866	6,089	0.72	641	665	423	439	1,105	60%	1.038
2021	5,548	5,548	0.78	574	574	287	287	861	67%	1

Note: Inflation-adjusted revenue (in 2021 dollars) used the Honolulu Consumer Price Index (CPI-U) https://www.bls.gov/regions/west/data/consumerpriceindex_honolulu_table.pdf
Source: PIFSC Socioeconomics Program: Fishery Economic Performance Measures. Pacific Islands Fisheries Science Center, Tier 1 data request, https://inport.nmfs.noaa.gov/inport/item/46097

2.5.4.2.3 Hawaii Ecosystem Component Species

Based on the new guideline for the archipelagic SAFE report from the Council, this section highlights the top 10 ecosystem component species (ECS; sorted by landings) and the priority ECS (recommended by the local fishery management agency) caught by small boats or shoreline fishing. Please note that the commercial data (the number of fishers/CML with MUS sold, pounds sold, and revenue) were sourced from the HDAR dealer reporting system, and the total participation and landings were sourced from the HDAR fisher reporting system.

Table 53 shows the commercial landings and revenue of the top 10 ECS in Hawaii in 2020 and 2021. The total pounds sold of the top 10 species/species groups in 2021 was nearly half a million pounds, valued at $1.68 million, slightly lower than 2020. Akule was the leading species of the top 10, which composed 51% of the total revenue of the top 10 in 2021. In addition, the ten fish species defined as the priority species (species of interest) for Hawaii are shown in Table 54. The total revenue of the 10 priority species also was 0.4 million dollars in 2021, a 25% decline from 2020.

Table 53. Top 10 ECS commercial landings, revenue, and price, 2020 and 2021

	2021							2020					
Local Name	# of Fishers	Pounds Kept	Pounds Sold	% of sold	Revenue	% of total	Price $/lb	# of Fishers	Pounds Kept	Pounds Sold	Revenue (adj.)	% of total	Price $/lb (adj.)
Akule	174	231,161	231,574	100%	850,853	51%	3.67	210	268,290	257,491	872,014	48%	3.38
Menpachi	138	47,706	42,953	90%	232,954	14%	5.42	163	60,795	55,648	297,113	16%	5.34
Opelu	93	83,055	69,300	83%	212,196	13%	3.06	115	70,990	52,103	165,336	9%	3.18
Uhu	44	23,742	15,443	65%	77,935	5%	5.05	49	42,046	30,715	150,446	8%	4.90
Taape	142	30,937	29,199	94%	63,009	4%	2.16	178	37,828	36,931	69,584	4%	1.89
Red Weke	41	12,609	12,578	100%	47,704	3%	3.79	50	20,625	22,289	80,998	4%	3.63
Opihi Alinalina	14	14,197	8,665	61%	65,424	4%	7.55	11	13,547	10,876	77,794	4%	7.15
Palani	42	24,506	27,068	110%	57,696	3%	2.13	47	28,103	28,192	54,669	3%	1.94
Kuahonu Crab	3	11,876	7,210	61%	43,353	3%	6.01						
Kala	23	12,486	14,982	120%	32,991	2%	2.20						
Kahala								146	14,624	1,684	2,860	0%	1.70
Manini								34	12,779	11,019	38,411	2%	3.49
Sum		492,275	458,972	93%	1,684,115		3.67		569,627	506,948	1,809,225		3.57

Table 54. Priority ECS commercial landings, revenue, and price, 2020 and 2021

	2021							2020					
Local Name	# of Fishers	Pounds Kept	Pounds Sold	% sold	Revenue ($)	% of total rev	Price $/lb	# of Fishers	Pounds Kept	Pounds Sold	Revenue (adj.)	% of total rev	Price $/lb (adj.)
Uhu	44	24,090	26,570	110%	137,821	34%	5.19	50	43,893	44,087	226,563	41%	5.14
Opihi	14	16,423	10,535	64%	79,515	19%	7.55	11	16,558	14,611	105,827	19%	7.25
Taape	142	30,937	29,199	94%	63,009	15%	2.16	178	37,828	36,931	69,584	13%	1.89
Manini	32	8,663	6,525	75%	22,099	5%	3.39	34	12,779	11,019	38,411	7%	3.49
Kala	23	12,486	14,982	120%	32,991	8%	2.2	31	11,302	11,412	23,427	4%	2.06
Nenue	26	8,468	7,885	93%	17,312	4%	2.2	32	9,346	9,505	20,053	4%	2.11
He'e (Day tako)	38	6,922	8,339	120%	37,478	9%	4.49	41	4,360	3,116	16,415	3%	5.27
Kumu	28	589	1,049	178%	13,140	3%	12.53	35	870	1,725	19,362	4%	11.22
Lobster	6	1,945	266	14%	2,482	1%	9.32	9	3,711	1,598	15,214	3%	9.52
Omilu	66	3,401	1,380	41%	4,443	1%	3.22	116	5,172	3,599	12,000	2%	3.33
Total		113,924	106,730	94%	**410,290**		3.84		145,819	137,603	**546,857**		3.97

2.5.5 Ongoing Research and Information Collection

PIFSC reports annually on the status of economic data collections for select regional commercial fisheries. This supports a national economic data monitoring effort known as the Commercial Fishing Economic Assessment Index (CFEAI). Details on the CFEAI and access to data from other regions is available at: https://www.st.nmfs.noaa.gov/data-and-tools/CFEAI-RFEAI/.

The table below represents the most recent data available for CFEAI metrics for select regional commercial fisheries for 2021. Entries for Hawaii insular fisheries are bolded in red. These values represent the most recent year of data for key economic data monitoring parameters (fishing revenues, operating costs, and fixed costs). The assessment column indicates the most recent publication year for specific economic assessments (returns above operating cost, profit), where available.

Table 55. Pacific Islands Region 2021 Commercial Fishing Economic Assessment Index

	2021 CFEAI				
	2021 Reporting Year (e.g. 1/2021-12/2021)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2021	2021	2013	2021	2016
ASam Longline	2021	2021	2016	2021	2019
HI Offshore Handline	2021	2014	2014	2019	2019
HI Small Boat (pelagic)	2021	2021	2021	2017	2019
HI Small Boat (bottomfish)	**2021**	**2021**	**2021**	**2017**	**2019**
HI Small Boat (reef)	**2021**	**2021**	**2021**	**2017**	**2019**
Guam Small boat	2021	2021	2019	2019	
CNMI Small boat	2021	2021	2019	2019	
ASam Small boat	2021	2021	2021	2019	

PIFSC fielded an update to the Hawaii small boat cost earnings survey (Chan and Pan 2017; Hospital et al. 2011) during calendar year 2021 (Chan 2022). This survey will provide updated information on operating costs and fixed costs for insular Hawaii small boat fisheries, as well as numerous elements related to fishing behavior, market participation, and fishery demographics.

PIFSC also generates projections for upcoming fiscal years, and the table below provides the projected CFEAI report for 2022 (*all projected activities and analyses are subject to funding*).

Table 56. Pacific Islands Region 2022 Commercial Fishing Economic Assessment Index

	2022 Projected CFEAI				
	2022 Reporting Year (e.g. 1/2022-12/2022)				
	Data			Assessment	
Pacific Islands Fisheries	Fishing Revenue Most Recent Year	Operating Cost Most Recent Year	Fixed Cost Most Recent Year	Returns Above Operating Costs (Quasi Rent) Assessment Most Recent Year	Profit Assessment Most Recent Year
HI Longline	2022	2022	2022	2022	2022
ASam Longline	2022	2022	2016	2022	2016
HI Offshore Handline	2022	2014	2014	2019	2019
HI Small Boat (pelagic)	2022	2021	2021	2022	2022
HI Small Boat (bottomfish)	**2022**	**2021**	**2021**	**2022**	**2022**
HI Small Boat (reef)	**2022**	**2021**	**2021**	**2022**	**2022**
Guam Small boat	2022	2022	2019	2019	
CNMI Small boat	2022	2022	2019	2019	
ASam Small boat	2022	2022	2021	2022	

PIFSC will continue to collect and monitor annual community social indicators (Kleiber et al. 2018; Hospital and Leong 2021) for Hawaii fishing communities, in accordance with a national project to describe and evaluate community well-being in terms of environmental justice, economic vulnerability, and gentrification pressure (https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-coastal-communities).

2.5.6 Relevant PIFSC Economics and Human Dimensions Publications: 2021

Publication	MSRA priority
Hedelin B, Gray S, Woehlke S, BenDor TK, Singer A, Jordan R, Zellner M, Giabbanelli P, Glynn P, Jenni K, Jetter A, Kolagani N, Laursen B, Leong KM, et al. 2021. What's left before participatory modeling can fully support real-world environmental planning processes: A case study review. Environmental Modelling & Software. 143:105073. https://doi.org/10.1016/j.envsoft.2021.105073	HC2.1.2 HC2.2.1 HC2.2.2 IF8.1.1
Hospital J, Leong K. 2021. Community Participation in Hawai'i Commercial Fisheries. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-119, 89 p. https://doi.org/10.25923/p4aj-k323	HC1.1.5
Hospital J, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19. 10p. (in: NOAA Fisheries National COVID-19 Preliminary Baseline Impact Assessment). https://media.fisheries.noaa.gov/2021-02/Initial-COVID-19-Impact-Assessment-webready.pdf	HC1.1.1 HC2.1.3 HC2.2.1
Hospital J, Iwane M, Kleiber D, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19 – Pacific Islands Snapshot March – July 2020. 10p. https://media.fisheries.noaa.gov/2021-02/Pacific-Islands-COVID-19-Impact-Snapshot-webready.pdf	HC1.1.1 HC2.1.3 HC2.2.1
Hospital J, Iwane M, Kleiber D, Leong K, Sweeney J. 2021. Pacific Islands Fisheries Impacts from COVID-19 (in NMFS. 2021. U.S. Seafood Industry and For-hire Sector Impacts from COVID-19: 2020 in Perspective. NOAA Tech. Memo. NMFS-SPO-221, 88 p. https://spo.nmfs.noaa.gov/sites/default/files/TM221.pdf	HC1.1.1 HC2.1.3 HC2.2.1
Iwane M, Leong KM, Kleiber D. 2021. Non-commercial Fishing in Policy, Practice, and Culture: Insights from the Papahanaumokuakea Marine National Monument. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-114, 43 p. https://doi.org/10.25923/r365-2f47	HC3.1.1 HC3.1.2 HC3.2.1 HC1.2.1
Iwane MA, Leong KM, Vaughan M, Oleson KL. 2021. When a shark is more than a shark: A sociopolitical problem-solving approach to fisher-shark interactions. Frontiers in Conservation Science. 2:10. https://doi.org/10.3389/fcosc.2021.669105	HC3.2.3 HC3.2.4 PS1.4.2 PS2.4.2
Johnson E, Champ JG, Leong K, Melena S. 2021. Content evaluation of the response to the centennial Find Your Park Campaign. Natural Resource Report. NPS/NRSS/NROC/NRR-2021/2242. National Park Service. Fort Collins, Colorado. https://doi.org/10.36967/nrr-2284970	HC3.2.4

Kasperski S, DePiper GS, Blake S, Colburn LL, Jepson M, Haynie AC, Karnauskas M, Leong KM, Lipton D, Masi M, et al. 2021. Assessing the State of Coupled Social-Ecological Modeling in Support of Ecosystem Based Fisheries Management in the U.S. Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.631400	HC2.1.1 HC2.1.2 HC2.1.4 IF8.1.1
Suan A, Leong KM, Oleson KLL. 2021. Automated content analysis of the Hawai'i small boat fishery survey reveals nuanced, evolving conflicts. Ecology and Society 26(4):9. https://doi.org/10.5751/ES-12708-260409	HC1.1.9 HC3.2.3
Tommasi D, deReynier YL, Townsend H, Harvey CJ, Satterthwaite W, Marshall KN, Kaplan IC, Brodie S, Field J, Hazen E, et al. 2021. A Case Study in Connecting Fisheries Management Challenges With Models and Analysis to Support Ecosystem-Based Management in the California Current Ecosystem. Frontiers in Marine Science. 8:776. https://doi.org/10.3389/fmars.2021.624161	IF8.1.1 IF8.1.6 HC2.1.2
Weijerman M. 2021. Development of an Atlantis model for Hawaii to support ecosystem-based management. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-113, 140 p. https://doi.org/10.25923/cwqb-1z04	IF8.1.1 IF8.1.6 HC2.1.2 HC2.1.4
Williams GD, Andrews KS, Brown JA, Gove JM, Hazen EL, Leong KM, Montenero KA, Moss JH, Rosellon-Druker JM, Schroeder ID, Siddon E. 2021. Place-Based Ecosystem Management: Adapting Integrated Ecosystem Assessment Processes for Developing Scientifically and Socially Relevant Indicator Portfolios. Coastal Management. 49(1):46-71. https://doi.org/10.1080/08920753.2021.1846154	IF8.1.1 HC2.2.1 HC3.1.3

2.6 PROTECTED SPECIES

This section of the report summarizes information on protected species interactions in fisheries managed under the Hawaii FEP. Protected species covered in this report include sea turtles, seabirds, marine mammals, sharks, and corals. Most of these species are protected under the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and/or the Migratory Bird Treaty Act (MBTA). A list of protected species found in or near Hawaii waters and a list of critical habitat designations in the Pacific Ocean are included in Appendix B.

2.6.1 Indicators for Monitoring Protected Species Interactions

This report monitors the status of protected species interactions in the Hawaii FEP fisheries using proxy indicators such as fishing effort and changes in gear types, as these fisheries do not have observer coverage. Creel surveys and logbook programs are not expected to provide reliable data about protected species interactions. Discussion of protected species interactions is focused on fishing operations in federal waters and associated transit through State waters.

2.6.1.1 FEP Conservation Measures

No specific regulations are in place to mitigate protected species interactions in the bottomfish, precious coral, coral reef ecosystem and crustacean fisheries currently active and managed under this FEP. Destructive gear such as bottom trawls, bottom gillnets, explosives, and poisons are prohibited under this FEP, and these prohibitions benefit protected species by preventing potential interactions with non-selective fishing gear.

The original crustacean Fishery Management Plan (FMP) and subsequent amendments included measures to minimize potential impacts of the Northwestern Hawaiian Islands (NWHI) component of the spiny lobster fishery to Hawaiian monk seals, such as specification of trap gear design and prohibition of nets. The Bottomfish and Seamount Groundfish FMP began requiring protected species workshops for the NWHI bottomfish fishery participants in 1988. These fisheries are no longer active due to the issuance of Executive Orders 13178 and 13196 and the subsequent Presidential Proclamations 8031 and 8112, which closed the fisheries within 50 nm around the NWHI.

2.6.1.2 ESA Consultations

Hawaii FEP fisheries are covered under the following consultations under section 7 of the ESA, through which NMFS has determined that these fisheries are not likely to jeopardize or adversely affect any ESA-listed species or critical habitat in the Hawaii Archipelago (Table 57).

Table 57. Summary of ESA consultations for Hawaii FEP Fisheries

Fishery	Consultation Date	Consultation Type[a]	Outcome[b]	Species
Bottomfish	3/18/2008	BiOp	LAA, non-jeopardy	Green sea turtle
			NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, northern right whale, sei whale, sperm whale, Hawaiian monk seal
	8/7/2013	BiOp modification	NLAA	False killer whale (MHI insular DPS)
	Initiated 2/1/2019	*Consultation ongoing*		Oceanic whitetip shark, giant manta ray, MHI false killer whale critical habitat
Coral Reef Ecosystem	5/22/2002	LOC (USFWS)	NLAA	Green, hawksbill, leatherback, loggerhead, and olive ridley turtles, Newell's shearwater, short-tailed albatross, Laysan duck, Laysan finch, Nihoa finch, Nihoa millerbird, Micronesian megapode, 6 terrestrial plants
	12/5/2013	LOC	NLAA	Loggerhead sea turtle (North Pacific DPS), leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, North Pacific right whale, sei whale, sperm whale, Hawaiian monk seal, false killer whale (MHI insular DPS)
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
Coral Reef Ecosystem (Kona Kampachi Special Coral Reef Ecosystem Fishing Permit only)	9/19/2013	LOC (USFWS)	NLAA	Short-tailed albatross, Hawaiian petrel, Newell's shearwater
	9/25/2013	LOC	NLAA	Loggerhead sea turtle (North Pacific DPS), leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, North Pacific right whale, sei whale, sperm whale, Hawaiian monk seal, false killer whale (MHI insular DPS)

Fishery	Consultation Date	Consultation Type[a]	Outcome[b]	Species
Crustacean	12/5/2013	LOC	NLAA	Loggerhead sea turtle (North Pacific DPS), leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, North Pacific right whale, sei whale, sperm whale, Hawaiian monk seal, false killer whale (MHI insular DPS)
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray, MHI false killer whale critical habitat
Precious Coral	12/5/2013	LOC	NLAA	Loggerhead sea turtle (North Pacific DPS), leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, North Pacific right whale, sei whale, sperm whale, Hawaiian monk seal, false killer whale (MHI insular DPS)
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray, MHI false killer whale critical habitat
All Fisheries	3/1/2016	LOC	NLAA	Hawaiian monk seal critical habitat

[a] BiOp = Biological Opinion; LOC = Letter of Concurrence.
[b] LAA = likely to adversely affect; NLAA = not likely to adversely affect.

2.6.1.2.1 Bottomfish Fishery

In a March 18, 2008 Biological Opinion (BiOp) covering MHI bottomfish fishery, NMFS determined that the MHI bottomfish fishery is likely to adversely affect but not likely to jeopardize the green sea turtle and included an incidental take statement (ITS) of two animals killed per year from collisions with bottomfish vessels. In the 2008 BiOp, NMFS also concluded that the fishery is not likely to adversely affect any four other sea turtle species (loggerhead, leatherback, olive ridley, and hawksbill turtles) and seven marine mammal species (humpback, blue, fin, Northern right whale, sei and sperm whales, and the Hawaiian monk seal).

In 2013, NMFS re-initiated consultation under ESA in response to listing of the MHI insular false killer whale distinct population segment (DPS) under the ESA. In a modification to the 2008 BiOp dated August 7, 2013, NMFS determined that commercial and non-commercial bottomfish fisheries in the MHI are not likely to adversely affect MHI insular false killer whale because of the spatial separation between the species and bottomfish fishing activities, the low likelihood of collisions, and the lack of observed or reported fishery interactions were among other reasons. NMFS also concluded that all previous determinations in the 2008 BiOp for other ESA-listed species and critical habitat remained valid.

In August 2015, NMFS revised the Hawaiian monk seal critical habitat in the NWHI and designated new critical habitat in the MHI. In an informal consultation completed on March 1, 2016, NMFS concluded that the Hawaii bottomfish fishery is not likely to adversely affect monk seal critical habitat.

On February 1, 2019, NMFS reinitiated consultation for the MHI bottomfish fisheries due to ESA listing of the oceanic whitetip shark and giant manta ray, and designation of main Hawaiian Islands insular false killer whale critical habitat. Also, on February 1, 2019, NMFS determined that the conduct of the Hawaii bottomfish fisheries during the period of consultation will not violate ESA Section 7(a)(2) and 7(d) (updated July 9, 2021).

2.6.1.2.2 Crustacean Fishery

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawaii crustacean fisheries are not likely to affect five sea turtle species (North Pacific loggerhead DPS, leatherback, olive ridley, green, and hawksbill turtles) and eight marine mammal species (humpback, blue, fin, North Pacific right whale, sei, and sperm whales, MHI insular false killer whale DPS and the Hawaiian monk seal). In an informal consultation completed on March 1, 2016, NMFS concluded that the Hawaii crustacean fishery is not likely to adversely affect monk seal critical habitat.

On September 18, 2018, NMFS concluded the Hawaii crustacean fishery will have no effect on the oceanic whitetip shark, giant manta ray, and MHI false killer whale critical habitat.

2.6.1.2.3 Coral Reef Ecosystem Fishery

On May 22, 2002, the USFWS concurred with the determination of NMFS that the activities conducted under the Coral Reef Ecosystems FMP are not likely to adversely affect ESA-listed species under USFWS's exclusive jurisdiction (i.e., seabirds) and ESA-listed species shared with NMFS (i.e., sea turtles).

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawaii coral reef ecosystem fisheries are not likely to affect five sea turtle species (North Pacific loggerhead DPS, leatherback, olive ridley, green, and hawksbill turtles) and eight marine mammal species (humpback, blue, fin, Northern right, sei, and sperm whales, MHI insular DPS false killer whales and the Hawaiian monk seal). In an informal consultation completed on March 1, 2016, NMFS concluded that the Hawaii coral reef ecosystem fishery is not likely to adversely affect monk seal critical habitat.

On September 18, 2018, NMFS concluded the Hawaii coral reef ecosystem fishery will have no effect on the oceanic whitetip shark and giant manta ray.

2.6.1.2.4 Precious Coral Fishery

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawaii precious coral fisheries are not likely to affect five sea turtle species (North Pacific loggerhead DPS, leatherback, olive ridley, green, and hawksbill turtles) and eight marine mammal species (humpback, blue, fin, North Pacific right, sei, and sperm whales, MHI insular false killer whale DPS and the Hawaiian monk seal). In an informal consultation completed on March 1, 2016, NMFS concluded that the Hawaii precious coral fishery is not likely to adversely affect monk seal critical habitat.

On September 18, 2018, NMFS concluded the Hawaii precious coral fishery will have no effect on the oceanic whitetip shark, giant manta ray, and MHI false killer whale critical habitat.

2.6.1.3 Non-ESA Marine Mammals

The MMPA requires NMFS to annually publish a List of Fisheries (LOF) that classifies commercial fisheries in one of three categories based on the level of mortality and serious injury of marine mammals associated with that fishery. According to the 2022 LOF (87 FR 23122, April 19, 2022), the bottomfish (HI bottomfish handline), precious coral (HI black coral diving), coral fish (HI spearfishing), and crustacean (HI crab trap, lobster trap, shrimp trap, crab net, Kona crab loop net, lobster diving) fisheries are classified as Category III fisheries (i.e., a remote likelihood of or no known incidental mortality and serious injury of marine mammals).

2.6.2 Status of Protected Species Interactions in the Hawaii FEP Fisheries

2.6.2.1 Bottomfish Fishery

2.6.2.1.1 Sea Turtle, Marine Mammal, and Seabird Interactions

Fisheries operating under the Hawaii FEP currently do not have federal observers on board. The NWHI component of the bottomfish fishery had observer coverage from 1990 to 1993 and 2003 to 2005. The NWHI observer program reported several interactions with non-ESA-listed seabirds during that time, and no interactions with marine mammals or sea turtles (Nitta 1999; WPRFMC 2017).

To date, there have been no reported interactions between MHI bottomfish fisheries and ESA-listed species of sea turtles, marine mammals, and seabirds. Furthermore, the commercial and non-commercial bottomfish fisheries in the MHI are not known to have the potential for a large and adverse effect on non-ESA-listed marine mammals. Although these species of marine mammals occur in the Exclusive Economic Zone (EEZ) waters where the fisheries operate and depredation of bait or catch by dolphins (primarily bottlenose dolphins) occurs (Kobayashi and Kawamoto 1995), there have been no observed or reported takes of marine mammals by the bottomfish fishery.

The 2008 BiOp included an ITS of two green turtle mortalities per year from collisions with bottomfish vessels. There have not been any reported or observed collisions of bottomfish vessels with green turtles, and data are not available to attribute stranded turtle mortality to collisions with bottomfish vessels. However, the BiOp analysis to determine the estimated level of take from vessel collisions was based on an estimated 71,800 bottomfish fishing trips per year. The total annual number of commercial and non-commercial bottomfish fishing trips since 2008 has been less than 3,500 per year. Therefore, the potential for collisions with bottomfish vessels is substantially lower than was estimated in the 2008 BiOp.

Based on fishing effort and other characteristics described in Chapter 1 of this report, no notable changes have been observed in the fishery. There is no other information to indicate that impacts to sea turtle, marine mammal, and seabird species from this fishery have changed in recent years.

2.6.2.1.2 Elasmobranch Interactions

As described in Section 2.6.1.2, ESA consultation for newly listed elasmobranch species is ongoing. Available information on elasmobranch interactions in the MHI bottomfish fishery is included here, based on the Biological Evaluation (BE) initiating ESA Section 7 consultation for the fishery (NMFS 2019).

A federal observer program monitored the Northwestern Hawaiian Islands (NWHI) bottomfish fishery from October 2003 to April 2006. Observer data from that period reported five interactions with oceanic whitetip sharks. However, a recent review of these data by the NMFS Observer Program indicated that species identification for these records is uncertain and some or all of these interactions could have been whitetip reef sharks (NMFS 2019). Additionally, the characteristics of the NWHI bottomfish fishery, which ceased operations in 2011 pursuant to the presidential proclamation establishing the Papahānaumokuākea Marine National Monument, differ from the MHI bottomfish fishery that operates today. The NWHI bottomfish fishery was comprised of larger vessels than those in the MHI due to the distance to the fishing grounds and was conducted solely by commercial fishermen using heavier gear than those used in the MHI.

Cooperative research fishing surveys conducted by Kendall Enterprise Incorporated and Pacific Islands Fisheries Group as part of the MHI Bottomfish Fishery-Independent Survey contract local Deep-7 commercial fishermen to collect data using a standardized traditional fishing method (Kendall Enterprise Inc. 2014). In the 2016 to 2017 surveys comprising 814 fishing samples (each sample being 30 minutes in duration) and 2,545 records of fish catch, three whitetip reef sharks and no oceanic whitetip sharks were recorded (PIFSC unpublished data, cited in NMFS 2019).

In addition to the bottomfish surveys, PIFSC researchers have conducted limited bottomfish fishing in the Pacific Islands region for life history research and fishery-independent survey purposes. Each research cruise may land a maximum of 1,200 kg of bottomfish. There have been seven such cruises in the Main Hawaiian Islands since 2007. However, there are no records of researchers catching oceanic whitetip sharks while conducting these activities (NMFS 2019).

The Hawaii Department of Aquatic Resources (DAR) CML reports has a single code for "whitetip sharks", and thus interactions with "whitetip sharks" could be either oceanic whitetip sharks or whitetip reef sharks. In the Hawaii commercial catch database, bottomfish fishermen recorded 23 sharks under the "whitetip sharks" reporting code between 2000 and 2017. Based on the area fished, the catch composition associated with the captured sharks, and the size of the shark, DAR ascertained that eight were likely oceanic whitetip sharks, of which four occurred in the NWHI (NMFS 2019).

Notwithstanding the sparsity of data and potential for species misidentification in self-reported data, available information indicates that oceanic whitetip shark captures in the MHI bottomfish fishery are rare. Sharks generally do not experience barotrauma when brought up from depth, and fishermen in Hawaii bottomfish fisheries tend to release hooked sharks alive by cutting their hook leaders (WPRFMC and NMFS 2007). However, quantitative estimates of post-release mortality are not available.

There are no records of giant manta ray incidental captures or entanglements in the federally managed bottomfish fisheries in Hawaii.

2.6.2.2 Crustacean, Coral Reef, and Precious Coral Fisheries

There are no observer data available for the crustacean, coral reef, or precious coral fisheries operating under the Hawaii FEP. However, based on current ESA consultations, these fisheries are not expected to interact with any ESA-listed species in federal waters around the Hawaii Archipelago. NMFS has also concluded that the Hawaii crustacean, coral reef, and precious coral commercial fisheries will not affect marine mammals in any manner not considered or authorized under the MMPA.

In 1986, one Hawaiian monk seal died as a result of entanglement with a bridle rope from a lobster trap. There have been no other reports of protected species interactions with any of these fisheries since then (WPRFMC 2009; WPRFMC 2017).

Based on fishing effort and other characteristics described in Chapter 1 of this report, no notable changes have been observed in these fisheries. There is no other information to indicate that impacts to protected species from this fishery have changed in recent years.

2.6.3 Identification of Emerging Issues

Table 58 summarizes current candidate ESA species, recent listing status, and post-listing activity (critical habitat designation and recovery plan development). Impacts from FEP-managed fisheries on any new listings and critical habitat designations will be considered in future versions of this report.

Table 58. Status of candidate ESA species, recent ESA listing processes, and post-listing activities

Species		Listing Process			Post-Listing Activity	
Common Name	**Scientific Name**	**90-Day Finding**	**12-Month Finding / Proposed Rule**	**Final Rule**	**Critical Habitat**	**Recovery Plan**
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Positive (81 FR 1376, 1/12/2016)	Positive, threatened (81 FR 96304, 12/29/2016)	Listed as threatened (83 FR 4153, 1/30/18)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (85 FR 12898, 3/5/2020)	In development; recovery planning workshops convened in 2019.
Giant Manta Ray	*Manta birostris*	Positive (81 FR 8874, 2/23/2016)	Positive, threatened (82 FRN 3694, 1/12/2017)	Listed as threatened (83 FR 2916, 1/22/18)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (84 FR 66652, 12/5/2019)	Recovery outline published 12/4/19 to serve as interim guidance until full recovery plan is developed; recovery planning workshop planned for 2021.

Species		Listing Process			Post-Listing Activity	
Common Name	**Scientific Name**	**90-Day Finding**	**12-Month Finding / Proposed Rule**	**Final Rule**	**Critical Habitat**	**Recovery Plan**
False Killer Whale (MHI Insular DPS)	*Pseudorca crassidens*	Positive (75 FR 316, 1/5/2010)	Positive, endangered (75 FR 70169, 11/17/2010)	Listed as endangered (77 FR 70915, 11/28/2012)	Designated in waters from the 45 m depth contour to the 3,200 m depth contour around the MHI from Niihau east to Hawaii (83 FR 35062, 07/24/2018)	Final Recovery Plan published November 3, 2021 (85 FR 60615)
Green Sea Turtle	*Chelonia mydas*	Positive (77 FR 45571, 8/1/2012)	Identification of 11 DPSs, endangered and threatened (80 FR 15271, 3/23/2015)	11 DPSs listed as endangered and threatened (81 FR 20057, 4/6/2016)	In development, proposal expected TBA	TBA
Giant Clams	*Hippopus hippopus, H. porcellanus, Tridacna costata, T. derasa, T. gigas, T. Squamosa, and T. tevoroa*	Positive (82 FR 28946, 06/26/2017)	TBA (status review ongoing)	TBA	N/A	N/A
Shortfin Mako Shark	*Isurus oxyrunchus*	Positive (86 FR 19863, 04/15/2021	TBA (status review ongoing)	TBA	N/A	N/A

2.6.4 Identification of Research, Data, and Assessment Needs

The following research, data, and assessment needs for insular fisheries were identified by the Council's Plan Team:

- Improve species identification of commercial and non-commercial fisheries data (e.g., outreach, use FAO species codes) to improve understanding of potential protected species impacts.
- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.
- Conduct genetic and telemetry research to improve understanding of population structure and movement patterns for listed elasmobranchs.

2.7 CLIMATE AND OCEANIC INDICATORS

2.7.1 Introduction

Over the past few years, the Council has incorporated climate change into the overall management of the fisheries over which it has jurisdiction. This 2020 annual SAFE report includes a now standard chapter on indicators of climate and oceanic conditions in the Western Pacific region. These indicators reflect global climate variability and change as well as trends in local oceanographic conditions.

The reasons for the Council's decision to provide and maintain an evolving discussion of climate conditions as an integral and continuous consideration in their deliberations, decisions, and reports are numerous:

- Emerging scientific and community understanding of the impacts of changing climate conditions on fishery resources, the ecosystems that sustain those resources, and the communities that depend upon them;
- Recent Federal Directives including the 2010 implementation of a National Ocean Policy that identified Resiliency and Adaptation to Climate Change and Ocean Acidification as one of nine National priorities as well as the development of a Climate Science Strategy by NMFS in 2015 and the subsequent development of the Pacific Islands Regional Action Plan for climate science; and
- The Council's own engagement with NOAA as well as jurisdictional fishery management agencies in American Samoa, CNMI, Guam, and Hawaii as well as fishing industry representatives and local communities in those jurisdictions.

In 2013, the Council began restructuring its Marine Protected Area/Coastal and Marine Spatial Planning Committee to include a focus on climate change, and the committee was renamed as the Marine Planning and Climate Change Committee (MPCCC). In 2015, based on recommendations from the committee, the Council adopted its Marine Planning and Climate Change Policy and Action Plan, which provided guidance to the Council on implementing climate change measures, including climate change research and data needs. The revised Pelagic FEP (February 2016) included a discussion on climate change data and research as well as a new objective (Objective 9) that states the Council should consider the implications of climate change in decision-making, with the following sub-objectives:

- To identify and prioritize research that examines the effects of climate change on Council-managed fisheries and fishing communities.
- To ensure climate change considerations are incorporated into the analysis of management alternatives.
- To monitor climate change related variables via the Council's Annual Reports.
- To engage in climate change outreach with U.S. Pacific Islands communities.

Beginning with the 2015 report, the Council and its partners began providing continuing descriptions of changes in a series of climate and oceanic indicators. The MPCCC was disbanded in early 2019, re-allocating its responsibilities among its members already on other committees or teams, such as the Fishery Ecosystem Plan Teams.

This annual report focuses previous years' efforts by refining existing indicators and improving communication of their relevance and status. Future reports will include additional indicators as the information becomes available and their relevance to the development, evaluation, and revision of the FEPs becomes clearer. Working with national and jurisdictional partners, the Council will make all datasets used in the preparation of this and future reports available and easily accessible.

2.7.2 Response to Previous Plan Team and Council Recommendations

There were no Council recommendations relevant to the climate and oceanic indicators section of the annual SAFE report for the Hawaii Archipelago in 2021.

2.7.3 Conceptual Model

In developing this chapter, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment (PIRCA) and the Ocean and Coasts chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee (NCADAC).

The Advisory Committee Report presented a possible conceptual framework designed to illustrate how climate factors can connect to and interact with other ecosystem components to ocean and coastal ecosystems and human communities. The Council adapted this model with considerations relevant to the fishery resources of the Western Pacific Region (Figure 14).

As described in the 2014 NCADAC report, the conceptual model presents a “simplified representation of climate and non-climate stressors in coastal and marine ecosystems.” For the purposes of this Annual Report, the modified Conceptual Model allows the Council and its partners to identify indicators of interest to be monitored on a continuing basis in coming years. The indicators shown in red were considered for inclusion in the Annual SAFE Reports, though the final list of indicators varied somewhat. Other indicators will be added over time as data become available and an understanding of the causal chain from stressors to impacts emerges.

The Council also hopes that this Conceptual Model can provide a guide for future monitoring and research. This guide will ideally enable the Council and its partners to move forward from observations and correlations to understanding the specific nature of interactions, and to develop capabilities to predict future changes of importance in the developing, evaluating, and adapting of FEPs in the Western Pacific region

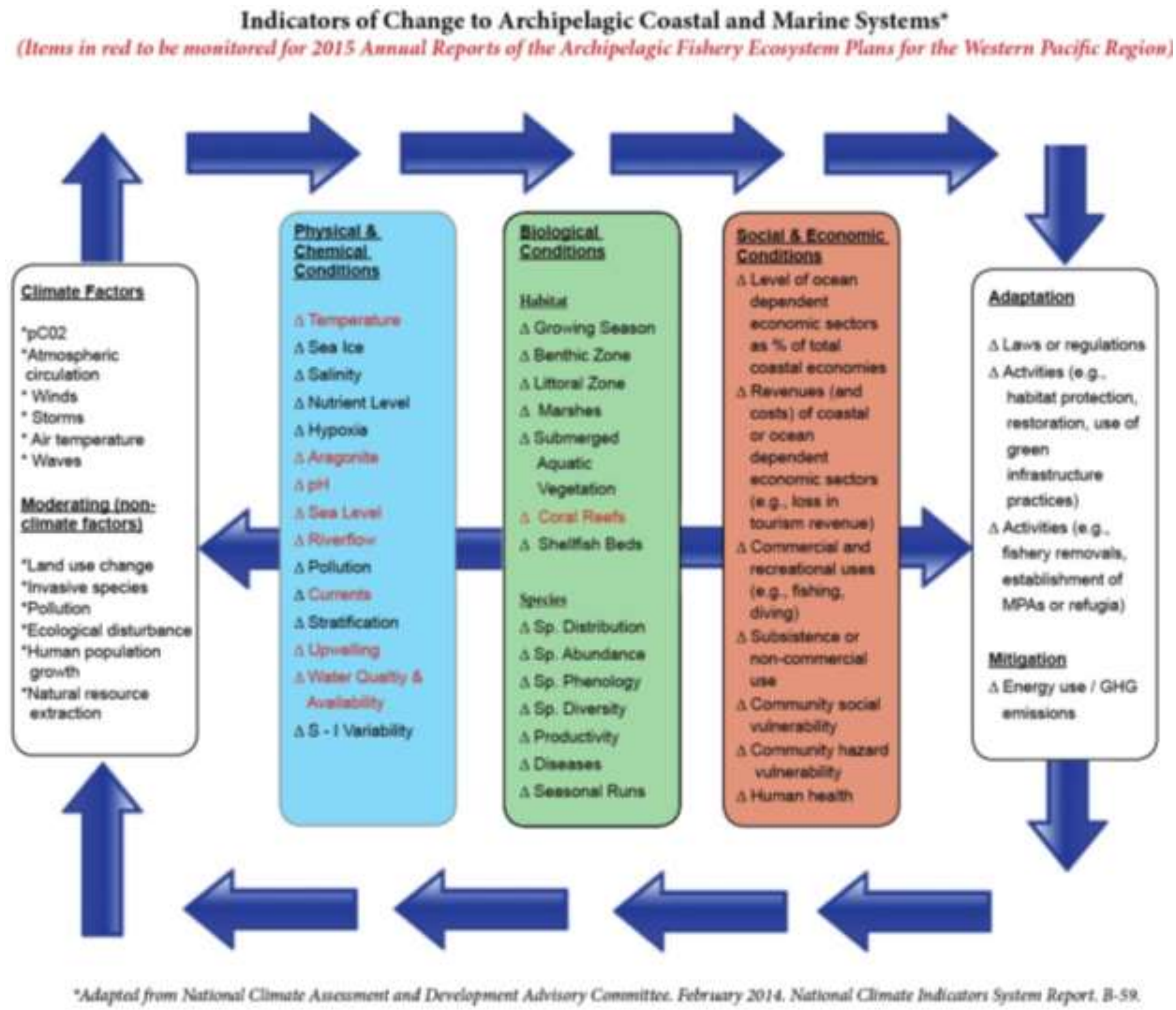

Figure 14. Indicators of change of archipelagic coastal and marine systems; conceptual model

2.7.4 Selected Indicators

The primary goal for selecting the indicators used in this (and future reports) is to provide fisheries-related communities, resource managers, and businesses with climate-related situational awareness. In this context, Indicators were selected to:

- Be fisheries relevant and informative;
- Build intuition about current conditions in light of changing climate;
- Provide historical context; and
- Recognize patterns and trends.

In this context, this section includes the following climate and oceanic indicators:

- Atmospheric concentration of carbon dioxide (CO_2)
- Oceanic pH at Station ALOHA;
- Oceanic Niño Index (ONI);
- Pacific Decadal Oscillation (PDO);
- Tropical cyclones;
- Sea surface temperature (SST);
- Coral Thermal Stress Exposure
- Chlorophyll-A
- Rainfall
- Sea Level (Sea Surface Height)

Figure 15 and Figure 16 provide a description of these indicators and illustrate how they are connected to each other in terms of natural climate variability and anthropogenic climate change.

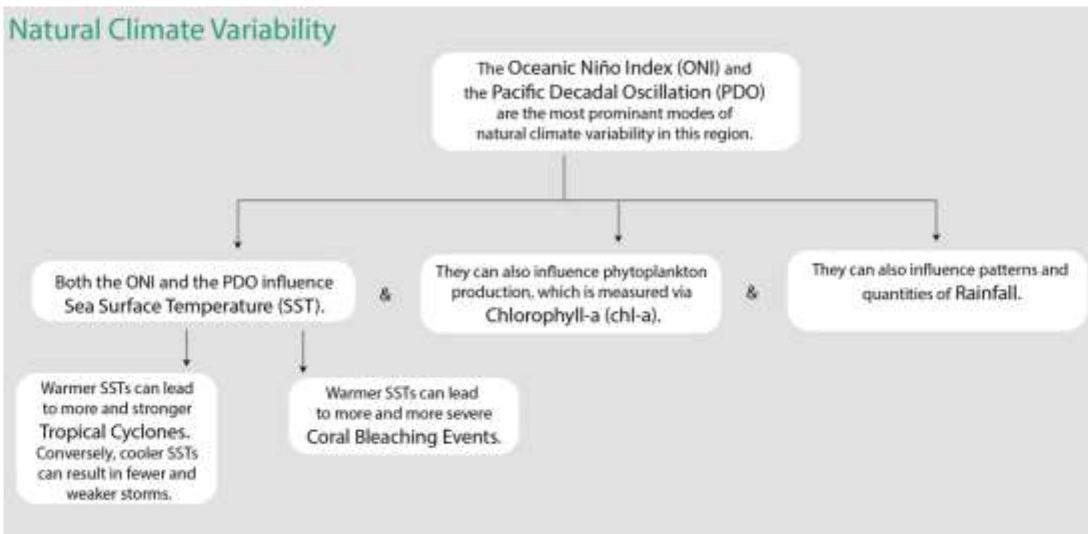

Figure 15. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability

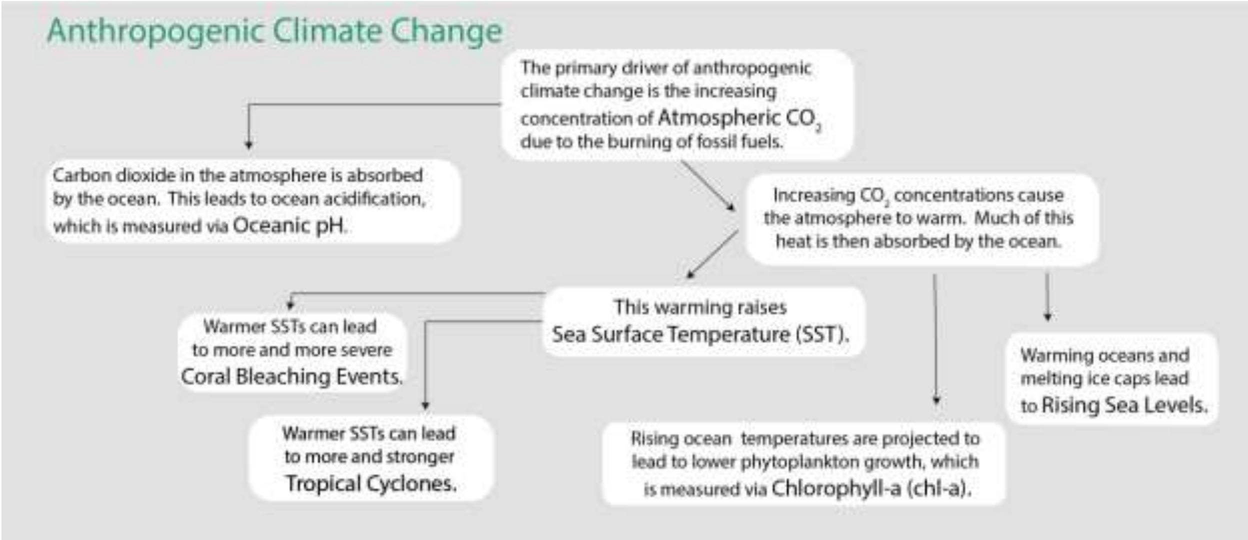

Figure 16. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change

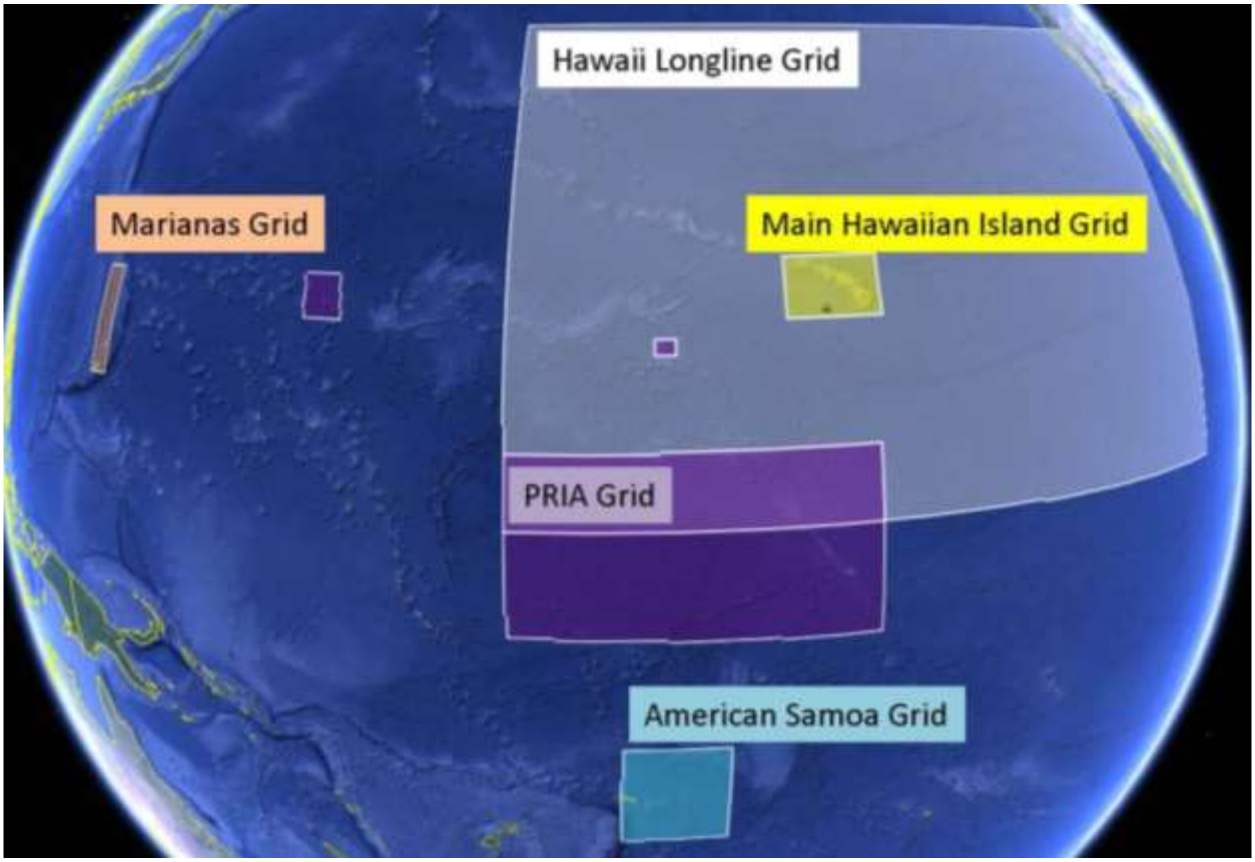

Figure 17. Regional spatial grids representing the scale of the climate change indicators being monitored

2.7.4.1 Atmospheric Concentration of Carbon Dioxide at Mauna Loa

Rationale: Atmospheric carbon dioxide (CO_2) is a measure of what human activity has already done to affect the climate system through greenhouse gas emissions. It provides quantitative information in a simplified, standardized format that decision makers can easily understand. This indicator demonstrates that the concentration (and, in turn, warming influence) of greenhouse gases in the atmosphere has increased substantially over the last several decades.

Status: Atmospheric CO_2 is increasing exponentially. This means that atmospheric CO_2 is increasing more quickly over time. In 2021, the annual mean concentration of CO_2 was 416 ppm. This is the highest annual value recorded. This year also saw the highest monthly value, which was 419 ppm. In 1959, the first year of the time series, the atmospheric concentration of CO_2 was 316 ppm. The annual mean passed 350 ppm in 1988, and 400 ppm in 2015.

Description: Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaiʻi in parts per million (ppm) from March 1958 to present. The observed increase in monthly average carbon dioxide concentration is primarily due to CO_2 emissions from fossil fuel burning. Carbon dioxide remains in the atmosphere for a very long time, and emissions from any location mix throughout the atmosphere in approximately one year. The annual variations at Mauna Loa, Hawaiʻi are due to the seasonal imbalance between the photosynthesis and respiration of terrestrial plants. During the summer growing season, photosynthesis exceeds respiration, and CO_2 is removed from the atmosphere. In the winter (outside the growing season), respiration exceeds photosynthesis, and CO_2 is returned to the atmosphere. The seasonal cycle is strongest in the northern hemisphere because of its larger land mass.

Timeframe: Annual, monthly.

Region/Location: Mauna Loa, Hawaii, but representative of global atmospheric carbon dioxide concentration.

Measurement Platform: *In-situ* station.

Data available at: https://gml.noaa.gov/ccgg/trends/data.html.

Sourced from: Keeling et al. (1976), Thoning et al. (1989), and NOAA (2022a).

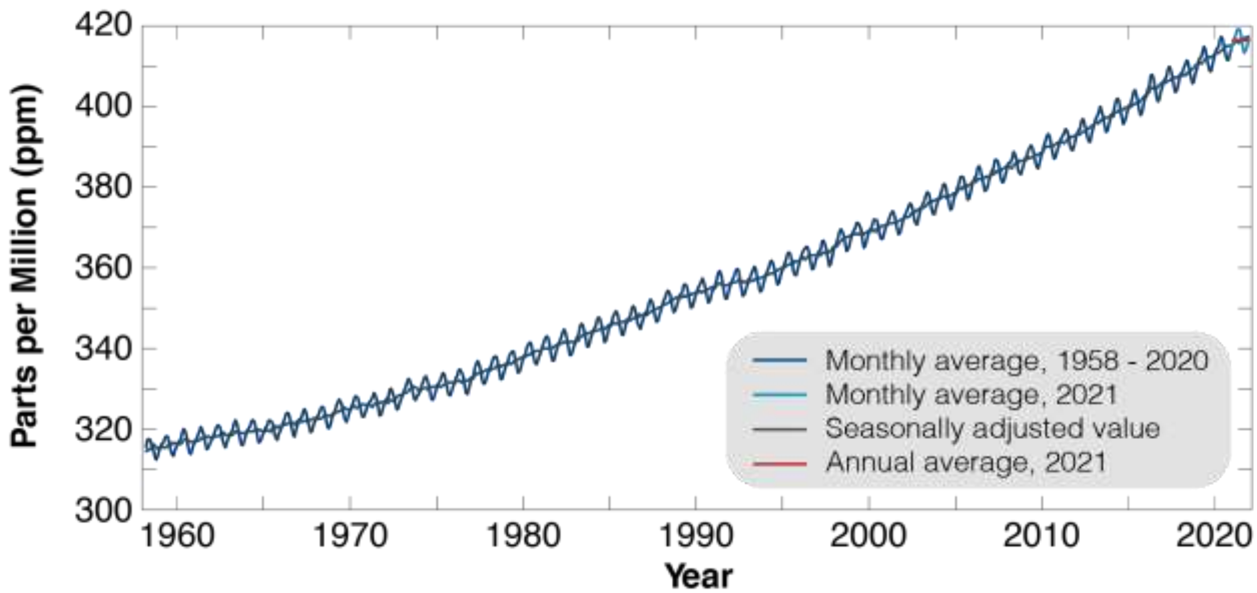

Figure 18. Monthly mean (black) and seasonally corrected (blue) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii

2.7.4.2 Oceanic pH

Rationale: Oceanic pH is a measure of how greenhouse gas emissions have already impacted the ocean. This indicator demonstrates that oceanic pH has decreased significantly over the past several decades (i.e., the ocean has become more acidic). Increasing ocean acidification limits the ability of marine organisms to build shells and other calcareous structures. Recent research has shown that pelagic organisms such as pteropods and other prey for commercially valuable fish species are already being negatively impacted by increasing acidification (Feely et al. 2016). The full impact of ocean acidification on the pelagic food web is an area of active research (Fabry et al. 2008).

Status: The ocean is roughly 10.2% more acidic than it was 30 years ago at the start of this time series. Over this time, pH has declined by 0.042 at a constant rate. In 2020, the most recent year for which data are available, the average pH was 8.07. Additionally, small variations seen over the course of the year are outside the range seen in the first year of the time series for the fourth year in a row. The highest pH value reported for the most recent year (8.077) is lower than the lowest pH value reported in the first year of the time series (8.083).

Description: Trends in surface (5 m) pH at Station ALOHA, north of Oahu (22.75°N, 158°W), collected by the Hawaiʻi Ocean Time Series (HOT) from October 1988 to 2020 (2021 data are not yet available). Oceanic pH is a measure of ocean acidity, which increases as the ocean absorbs carbon dioxide from the atmosphere. Lower pH values represent greater acidity. Oceanic pH is calculated from total alkalinity (TA) and dissolved inorganic carbon (DIC). Total alkalinity represents the ocean's capacity to resist acidification as it absorbs CO_2 and the amount of CO_2 absorbed is captured through measurements of DIC. The multi-decadal time series at Station ALOHA represents the best available documentation of the significant downward trend in oceanic pH since the time series began in 1988. Oceanic pH varies over both time and space, though the conditions at Station ALOHA are considered broadly representative of those across the Western and Central Pacific's pelagic fishing grounds.

Timeframe: Monthly.

Region/Location: Station ALOHA: 22.75°N, 158°W.

Measurement Platform: *In-situ* station.

Data available at: https://hahana.soest.hawaii.edu/hot/hot-dogs/bseries.html.

Sourced from: Fabry et al. (2008), Feely et al. (2016), and the Hawaiʻi Ocean Time Series as described in Karl and Lukas (1996) and on its website (HOT 2022) using the methodology provided by Zeebe and Wolf-Gladrow (2001).

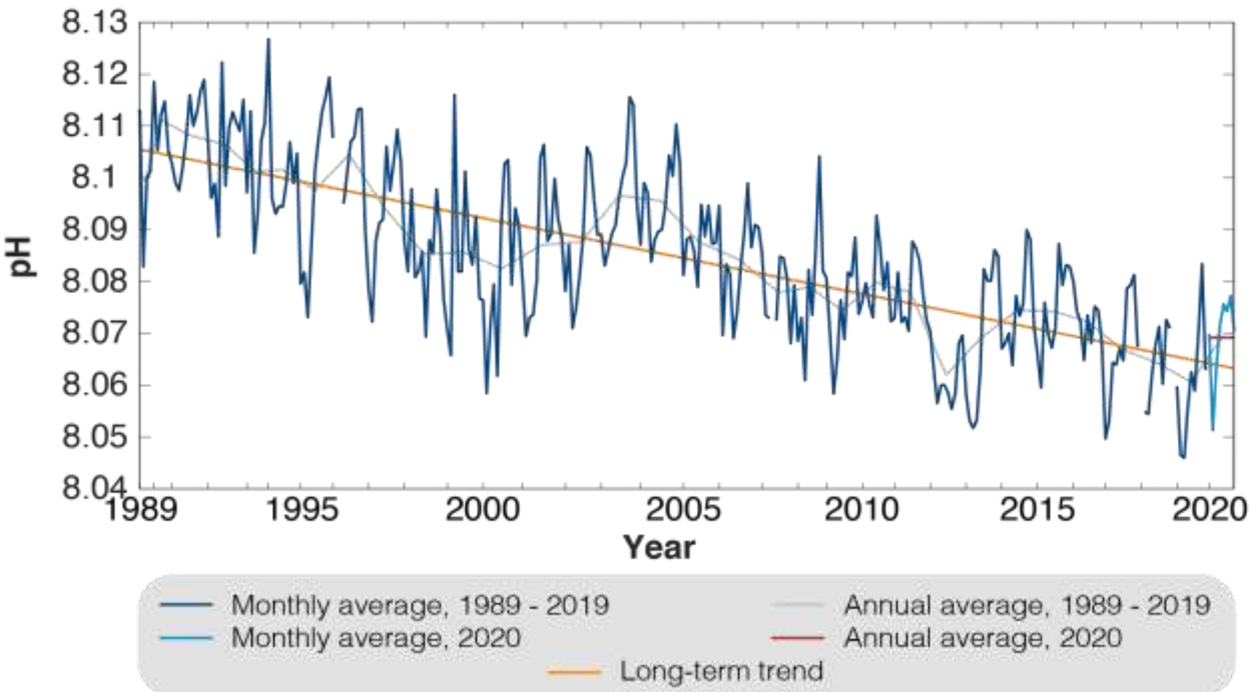

Figure 19. Time series and long-term trend of oceanic pH measured at Station ALOHA from 1989-2020

2.7.4.3 Oceanic Niño Index

Rationale: The El Niño – Southern Oscillation (ENSO) cycle is known to have impacts on Pacific fisheries including tuna fisheries. The ONI focuses on ocean temperature, which has the most direct effect on these fisheries.

Status: The ONI indicated La Niña conditions for most of 2021, with two consecutive neutral seasons punctuating the year mid-year. In 2021, the ONI ranged from -1.1 to -0.4. This is within the range of values observed previously in the time series.

Description: The three-month running mean (referred to as a season) of satellite remotely-sensed sea surface temperature (SST) anomalies in the Niño 3.4 region (5°S – 5°N, 120° – 170°W). The Oceanic Niño Index (ONI) is a measure of the El Niño – Southern Oscillation (ENSO) phase. Warm and cool phases, termed El Niño and La Niña respectively, are based in part on an ONI threshold of ± 0.5 °C being met for a minimum of five consecutive overlapping seasons. Additional atmospheric indices are needed to confirm an El Niño or La Niña event, as the ENSO is a coupled ocean-atmosphere phenomenon. The atmospheric half of ENSO is measured using the Southern Oscillation Index.

Timeframe: Every three months.

Region/Location: Niño 3.4 region, 5°S – 5°N, 120° – 170°W.

Measurement Platform: *In-situ* station, satellite, model.

Data available at: https://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt.

Sourced from NOAA CPC (2022).

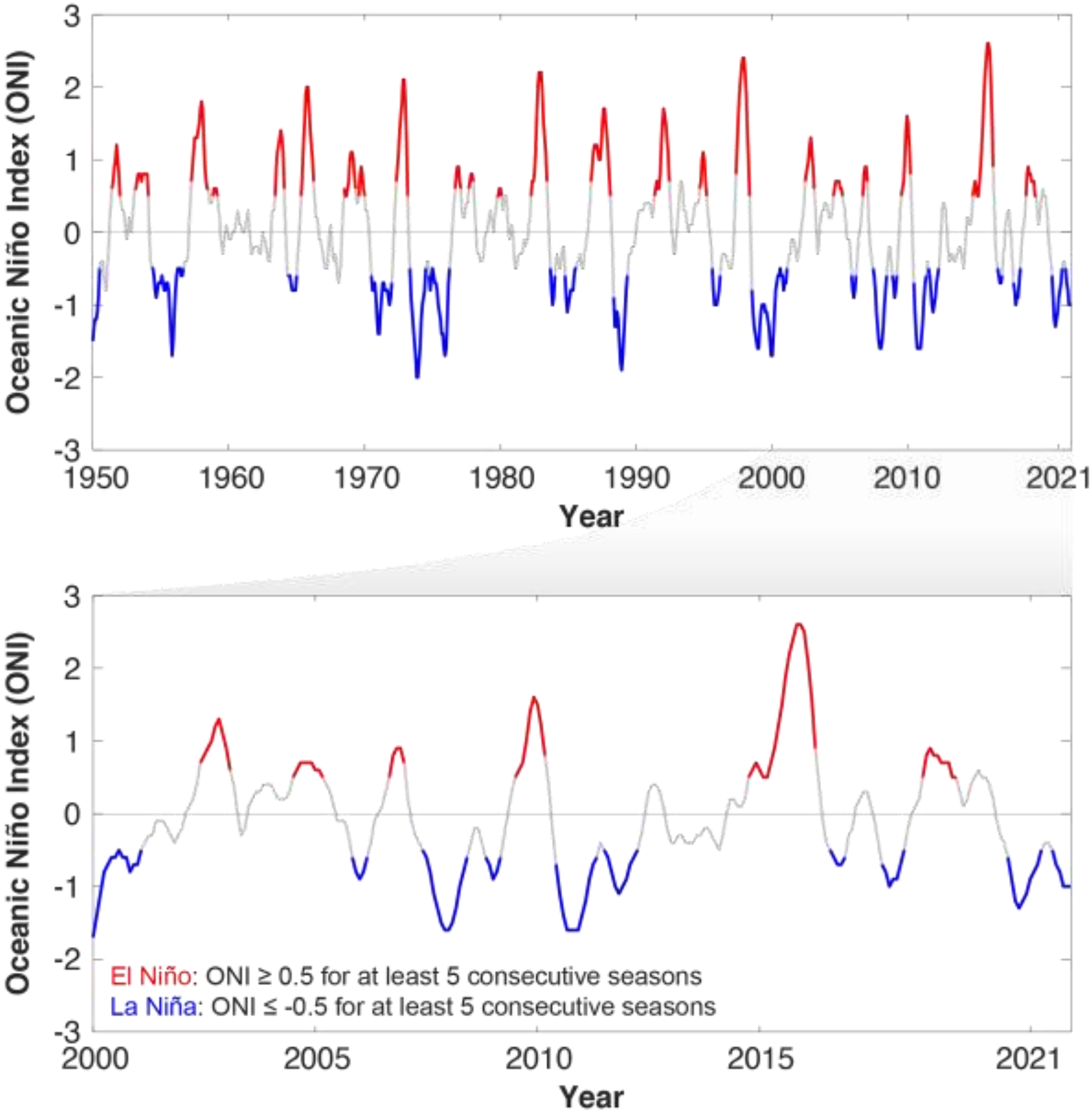

Figure 20. Oceanic Niño Index from 1950-2021 (top) and 2000–2021 (bottom) with El Niño periods in red and La Niña periods in blue

2.7.4.4 Pacific Decadal Oscillation

Rationale: The Pacific Decadal Oscillation (PDO) was initially named by fisheries scientist Steven Hare in 1996 while researching connections between Alaska salmon production cycles and Pacific climate. Like ENSO, the PDO reflects changes between periods of persistently warm or persistently cool ocean temperatures, but over a period of 20 to 30 years (versus six to 18 months for ENSO events). The climatic fingerprints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Status: The PDO was negative in 2021. The index ranged from -2.66 to -0.56 over the course of the year. This is within the range of values observed previously in the time series.

Description: The PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability. As seen with the better-known ENSO, extremes in the PDO pattern are marked by widespread variations in the Pacific Basin and the North American climate. In parallel with the ENSO phenomenon, the extreme cases of the PDO have been classified as either warm or cool, as defined by ocean temperature anomalies in the northeast and tropical Pacific Ocean. When SST is below average in the [central] North Pacific and warm along the North American coast, and when sea level pressures are below average in the North Pacific, the PDO has a positive value. When the climate patterns are reversed, with warm SST anomalies in the interior and cool SST anomalies along the North American coast, or above average sea level pressures over the North Pacific, the PDO has a negative value. Description inserted from NOAA (2021b).

Timeframe: Annual, monthly.

Region/Location: Pacific Basin north of 20°N.

Measurement Platform: *In-situ* station, satellite, model.

Data available at: https://psl.noaa.gov/pdo/.

Sourced from: NOAA (2022b), Mantua (1997), and Newman (2016).

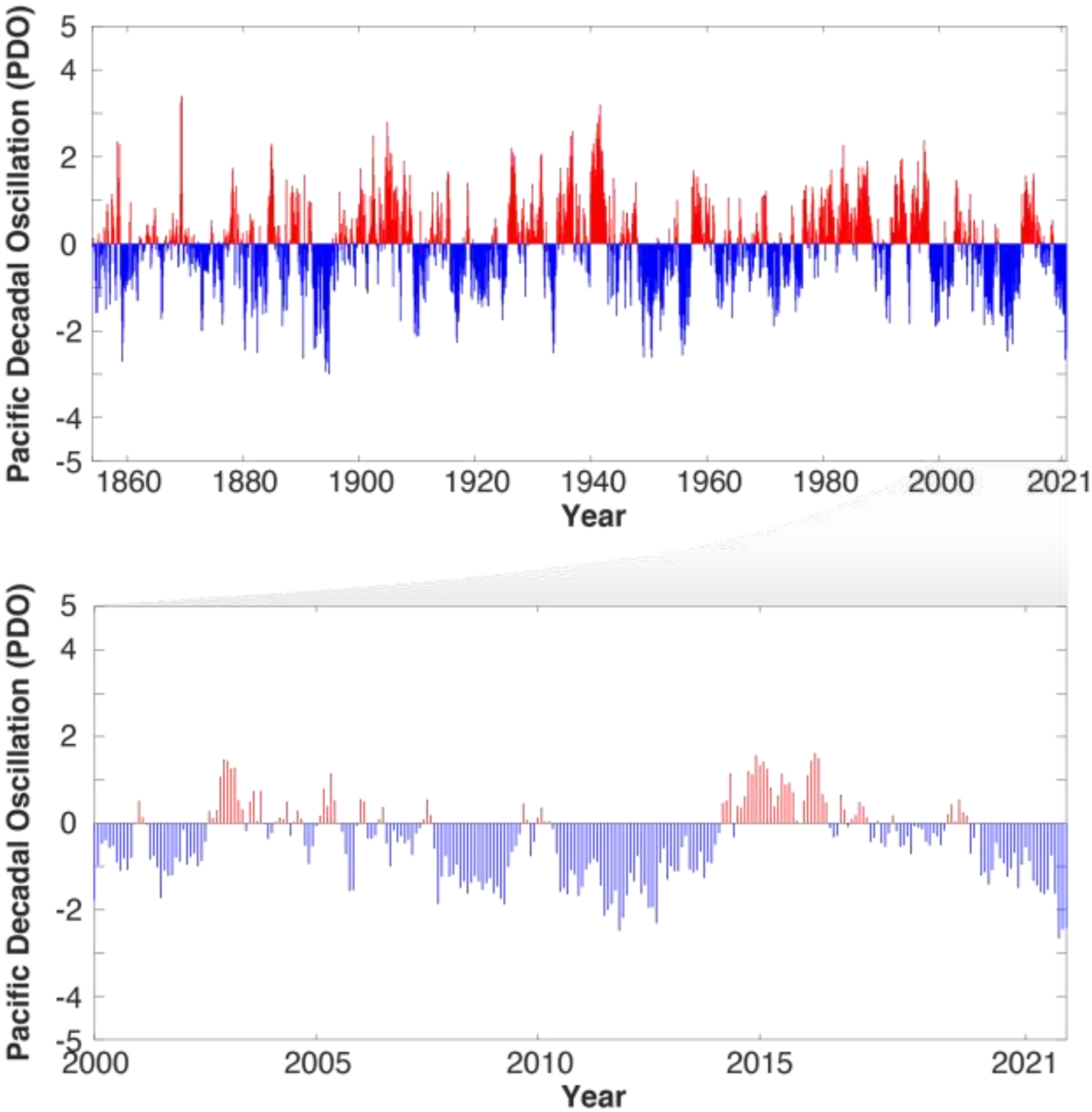

Figure 21. Pacific Decadal Oscillation from 1950–2021 (top) and 2000–2021 (bottom) with positive warm periods in red and negative cool periods in blue

2.7.4.5 Tropical Cyclones

Rationale: The effects of tropical cyclones are numerous and well known. At sea, storms disrupt and endanger shipping traffic as well as fishing effort and safety. The Hawaiʻi longline fishery, for example, has had serious problems with vessels dodging storms at sea, delayed departures, and inability to make it safely back to Honolulu because of bad weather. When cyclones encounter land, their intense rains and high winds can cause severe property damage, loss of life, soil erosion, and flooding. Associated storm surge, the large volume of ocean water pushed toward shore by cyclones' strong winds, can cause severe flooding and destruction.

Status:

Eastern North Pacific. In the East Pacific in 2021, the 19 named storms and eight hurricanes were both near normal. However, only two storms became major hurricanes, which is less than half of normal. The Accumulated Cyclone Energy (ACE) was also about 30% below the 1991–2020 average. The beginning and end of the hurricane season were noteworthy. The East Pacific had four named storms in June, which tied for the 4th most on record. The total of five for the year through June tied a record as well. Additionally, two tropical cyclones formed in November in the eastern Pacific basin. Based on a 30-year climatology (1991–2020), one named storm typically forms in November every second or third year. However, this is the fourth straight November with at least one named storm forming. In addition, both Sandra and Terry were tropical storms simultaneously, which is the first time this has occurred in the eastern Pacific in November.

Summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202113#summary, https://www.nhc.noaa.gov/text/MIATWSEP.shtml, and https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202106.

Central North Pacific. Tropical cyclone activity in the central Pacific in 2021 was below the 1991–2020 average. There was only one named storm, which did not reach hurricane status. However, the remnants of the Eastern Pacific's Hurricane Linda caused heavy rainfall over the main Hawaiian Islands in August. On average (1991–2020), the central Pacific sees four named storms, two hurricanes, and one major hurricanes. The 2021 ACE index was about two orders of magnitude, or roughly 100 times, below the 1991–2020 average. Information on Hurricane Linda inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202108.

Western North Pacific. Tropical cyclone activity was below the 1991–2020 average in 2021. The 23 named storms in the West Pacific in 2021 was near normal (1991–2020), but the ten typhoons and five typhoons were both among the five lowest years since 1981. The ACE was also about 30% below the 1991–2020 average in the West Pacific. Portions of the summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202113#summary

South Pacific. Tropical cyclone activity in the South Pacific was roughly average in 2021. The 10 named storms, 4 cyclones, and 2 major cyclones were very close to the 1991–2020 average of 9 named storms, 5 cyclones and 2 major cyclones. The 2021 ACE index was also close to the 1991–2020 average. Of note, the South Pacific produced two named storms in late January, including Tropical Cyclone Ana. Ana brought heavy rain and flooding to Fiji, which has been impacted by an unusual number of tropical cyclones in 2020–2021. Portions of the summary inserted from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202101

Description: This indicator uses historical data from the NOAA National Climate Data Center (NCDC) International Best Track Archive for Climate Stewardship to track the number of tropical cyclones in the western, central, eastern, and southern Pacific basins. This indicator also monitors the Accumulated Cyclone Energy (ACE) Index and the Power Dissipation Index which are two ways of monitoring the frequency, strength, and duration of tropical cyclones based on wind speed measurements.

The annual frequency of storms passing through each basin is tracked and Figure 22 shows the representative breakdown of Saffir-Simpson hurricane categories.

Every cyclone has an ACE Index value, which is a number based on the maximum wind speed measured at six-hourly intervals over the entire time that the cyclone is classified as at least a tropical storm (wind speed of at least 34 knots; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. Figure 23 shows the ACE values for each hurricane/typhoon season and has a horizontal line representing the average annual ACE value.

Timeframe: Annual.

Region/Location:

Eastern North Pacific: east of 140° W, north of the equator.

Central North Pacific: 180° - 140° W, north of the equator.

Western North Pacific: west of 180°, north of the equator.

South Pacific: south of the equator.

Measurement Platform: Satellite.

Data available at: https://www.ncei.noaa.gov/data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/csv.

Sourced from: Knapp et al. (2010), Knapp et al. (2018), and NOAA (2022c).

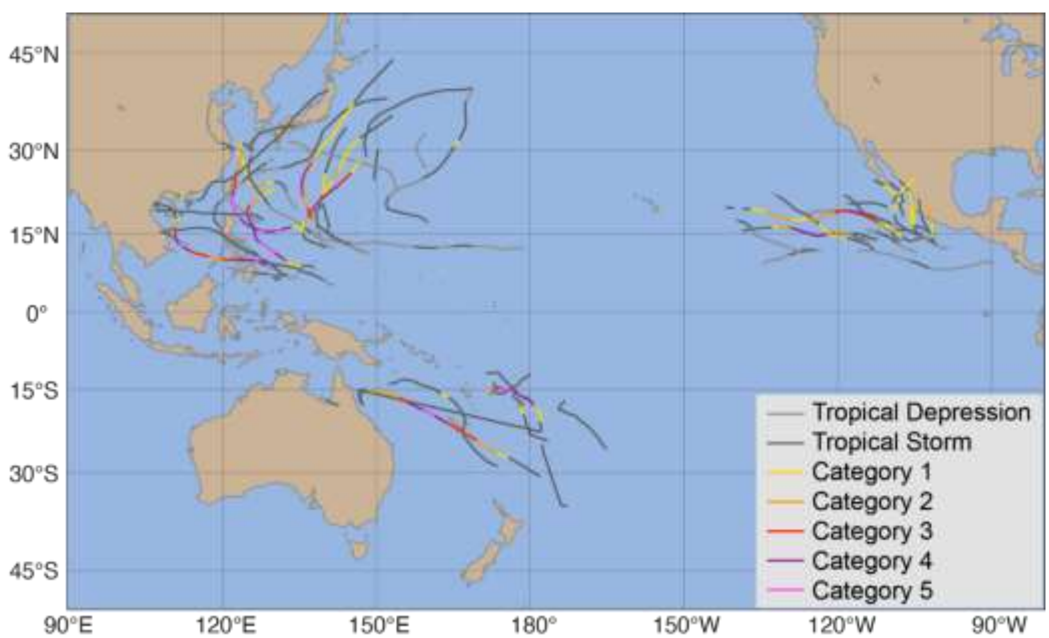

Figure 22. 2021 Pacific basin tropical cyclone tracks

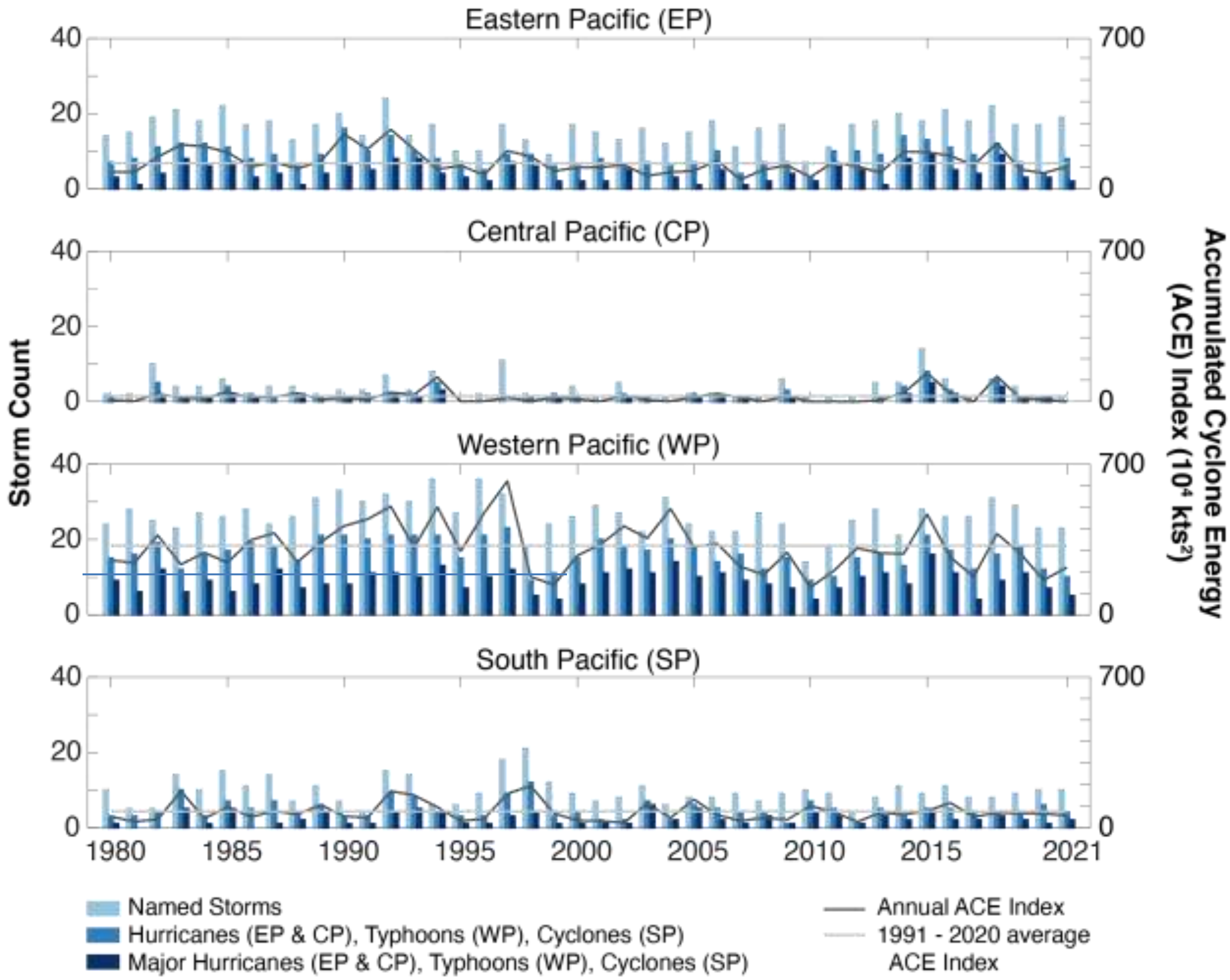

Figure 23. 2021 tropical storm totals by region

2.7.4.6 Sea Surface Temperature & Anomaly

Rationale: Sea surface temperature (SST) is one of the most directly observable existing measures for tracking increasing ocean temperatures. SST varies in response to natural climate cycles such as the El Niño – Southern Oscillation (ENSO) and is projected to rise as a result of anthropogenic climate change. Both short-term variability and long-term trends in SST impact the marine ecosystem. Understanding the mechanisms through which organisms are impacted and the time scales of these impacts is an area of active research.

Status*:* Annual mean SST was 25.67ºC in 2021. Over the period of record, annual SST has increased at a rate of 0.0168 ºC yr^{-1}. Monthly SST values in 2021 ranged from 24.47 – 26.64 ºC, outside the climatological range of 23.29 – 28.48 ºC. The annual anomaly was 0.13 ºC hotter than average, with some intensification in the northern part of the region, and a colder than usual area south-east of Hawaii Island.

Note that from the top to bottom in Figure 24, panels show climatological SST (1985-2020), 2021 SST anomaly, time series of monthly mean SST, and time series of monthly SST anomaly.

Description: Satellite remotely-sensed monthly sea surface temperature (SST) is averaged across the Main Hawaiian Island Grid (18.5° – 22.5°N, 161° – 154°W). A time series of monthly mean SST averaged over the Main Hawaiian Island region is presented. Additionally, spatial climatology and anomalies are shown. Data from NOAA Coral Reef Watch CoralTemp v3.1 (NOAA 2022).

Timeframe: Monthly.

Region/Location: Main Hawaiian Island Grid (18.5° – 22.5°N, 161° – 154°W).

Measurement Platform: Satellite.

Sourced from: NOAA OceanWatch (2022a).

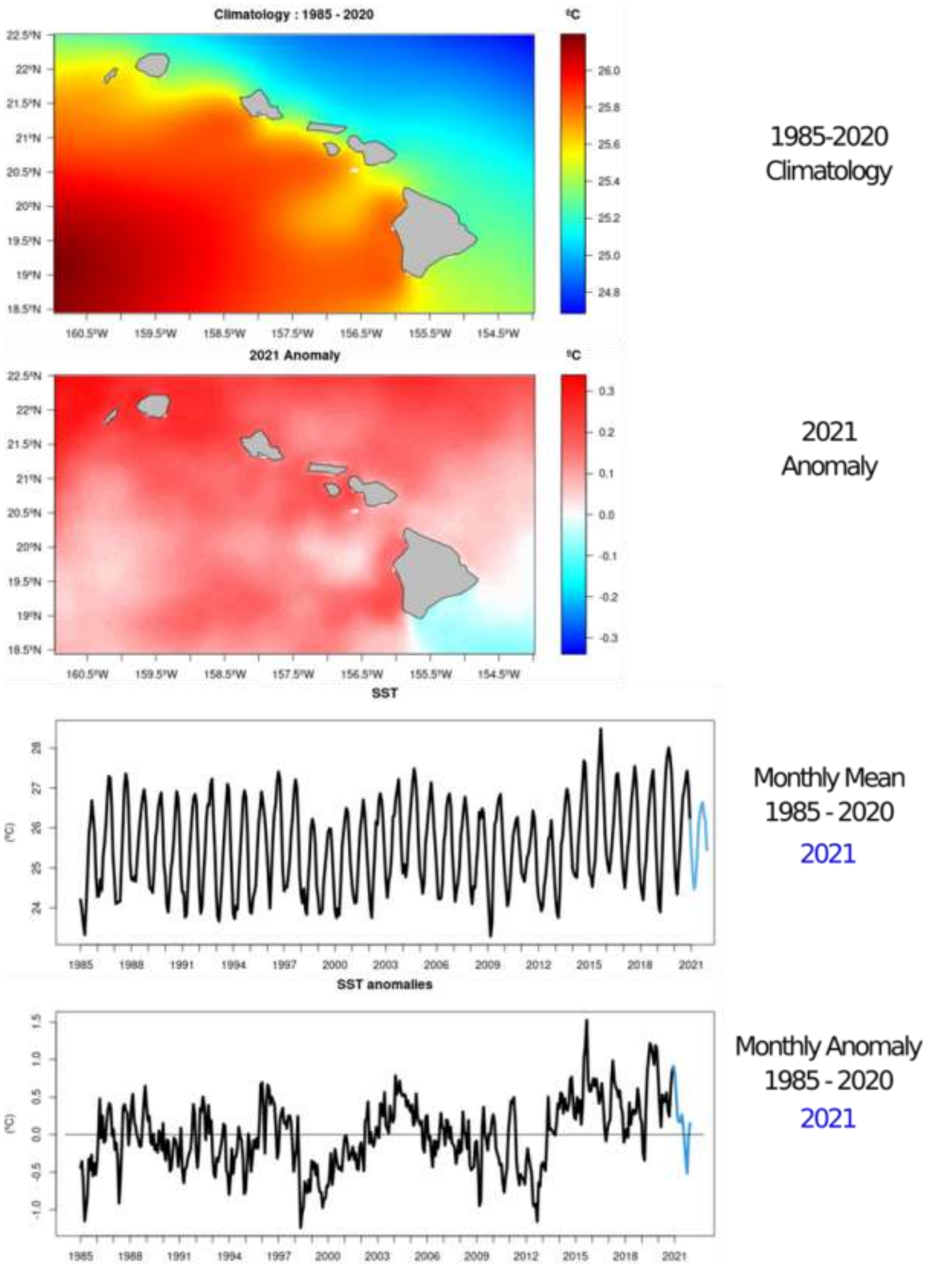

Figure 24. Sea surface temperature climatology and anomalies from 1985-2021

2.7.4.7 Coral Thermal Stress Exposure: Degree Heating Weeks

Rationale: Degree heating weeks are one of the most widely used metrics for assessing exposure to coral bleaching-relevant thermal stress.

Status: After a series of stress events in 2014, 2015, and 2019, the main Hawaiian Islands experienced no coral heat stress in 2021.

Description: Here we present a metric of exposure to thermal stress that is relevant to coral bleaching. Degree Heating Weeks (DHW) measure time and temperature above a reference 'summer maximum', presented as rolling sum weekly thermal anomalies over a 12-week period. Higher DHW measures imply a greater likelihood of mass coral bleaching or mortality from thermal stress.

The NOAA Coral Reef Watch program uses satellite data to provide current reef environmental conditions to quickly identify areas at risk for coral bleaching. Bleaching is the process by which corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and death become likely.

The NOAA Coral Reef Watch (CRW) daily 5-km satellite coral bleaching Degree Heating Week (DHW) product presented here shows accumulated heat stress, which can lead to coral bleaching and death. The scale goes from 0 to 20 °C-weeks. The DHW product accumulates the instantaneous bleaching heat stress (measured by Coral Bleaching HotSpots) during the most-recent 12-week period. It is directly related to the timing and intensity of coral bleaching. Significant coral bleaching usually occurs when DHW values reach 4 °C-weeks. By the time DHW values reach 8 °C-weeks, widespread bleaching is likely and significant mortality can be expected (NOAA Coral Reef Watch 2022).

Timeframe: 2014-2021, Daily data.

Region/Location: Global.

Sourced from: NOAA Coral Reef Watch (2022).

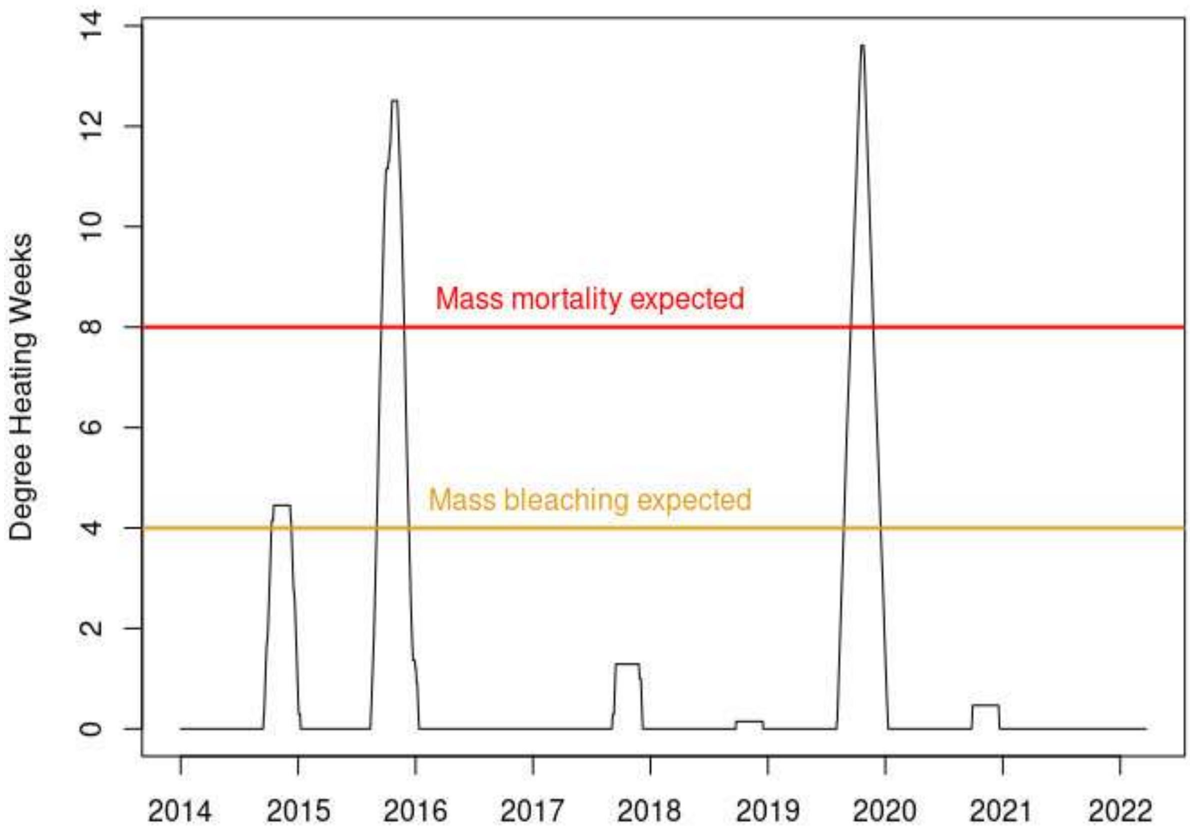

Figure 25. Coral Thermal Stress Exposure, Main Hawaiian Island Virtual Station from 2014-2021, measured in Coral Reef Watch Degree Heating Weeks

2.7.4.8 Chlorophyll-A and Anomaly

Rationale: Chlorophyll-A is one of the most directly observable measures we have for tracking increasing ocean productivity.

Status: Annual mean Chl-A was 0.084 mg/m^3 in 2020. Over the period of record, annual Chl-A has shown no significant temporal trend. Monthly Chl-A values in 2021 ranged from 0.069-0.10 mg/m^3, within the climatological range of 0.057 – 0.121 mg/m^3. The annual anomaly was 0.0049 mg/m^3 higher than average.

Description: Chlorophyll-A Concentration from 1998-2021, derived from the ESA Ocean Color Climate Change Initiative dataset, v5.0. A monthly climatology was generated across the entire period (1998-2020) to provide both a 2021 spatial anomaly, and an anomaly time series.

ESA Ocean Color Climate Change Initiative dataset is a merged dataset, combining data from SeaWIFS, MODIS-Aqua, MERIS, and VIIRS to provide a homogeneous time-series of ocean color. Data was accessed from the OceanWatch Central Pacific portal.

Timeframe: 1998-2021, Daily data available, Monthly means shown.

Region/Location: Global.

Measurement Platform: SeaWIFS, MODIS-Aqua, MERIS, and VIIRS

Sourced from: NOAA OceanWatch (2022b).

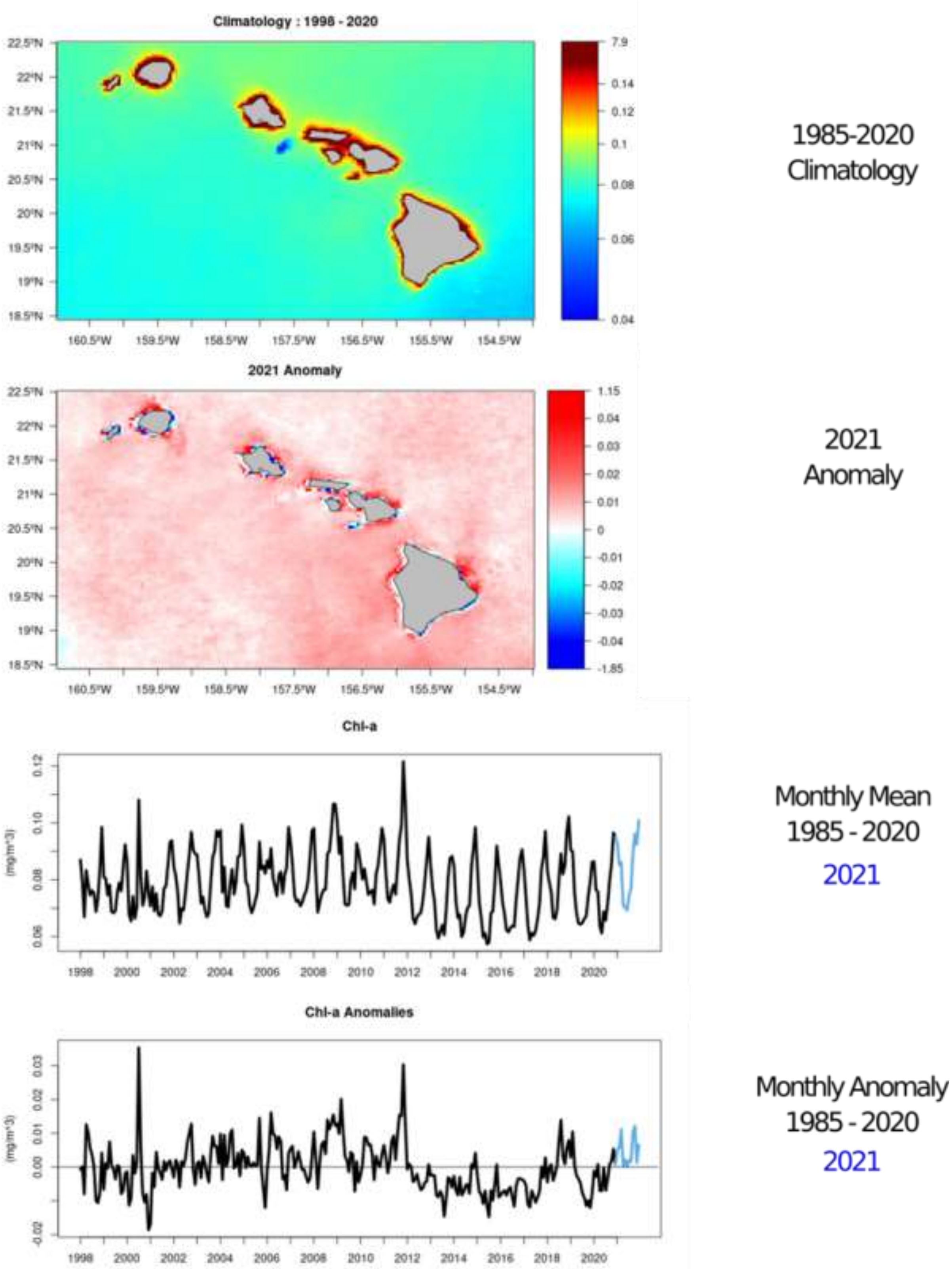

Figure 26. Chlorophyll-*a* (Chl-A) and Chl-A Anomaly from 1998-2021

2.7.4.9 Rainfall

Rationale: Rainfall may have substantive effects on the nearshore environment and is a potentially important co-variate with the landings of particular stocks.

Description: The CPC Merged Analysis of Precipitation (CMAP) is a technique which produces pentad and monthly analyses of global precipitation in which observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms, such as infrared and microwave (NOAA 2002). The analyses are on a 2.5 x 2.5-degree latitude/longitude grid and extend back to 1979. CMAP Precipitation data are provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their website at https://www.esrl.noaa.gov/psd/. The data are comparable (but should not be confused with) similarly combined analyses by the Global Precipitation Climatology Project described in Huffman et al. (1997).

It is important to note that the input data sources to make these analyses are not constant throughout the period of record. For example, SSM/I (passive microwave - scattering and emission) data became available in July 1987; prior to that the only microwave-derived estimates available are from the MSU algorithm (Spencer, 1993) which is emission-based thus precipitation estimates are available only over oceanic areas. Furthermore, high temporal resolution IR data from geostationary satellites (every 3-hr) became available during 1986; prior to that, estimates from the OPI technique (Xie and Arkin 1997) are used based on OLR from orbiting satellites.

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the rain gauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988).

Timeframe: Monthly.

Region/Location: Global.

Measurement Platform: *In-situ* station gauges and satellite data.

Sourced from: APDRC (2022).

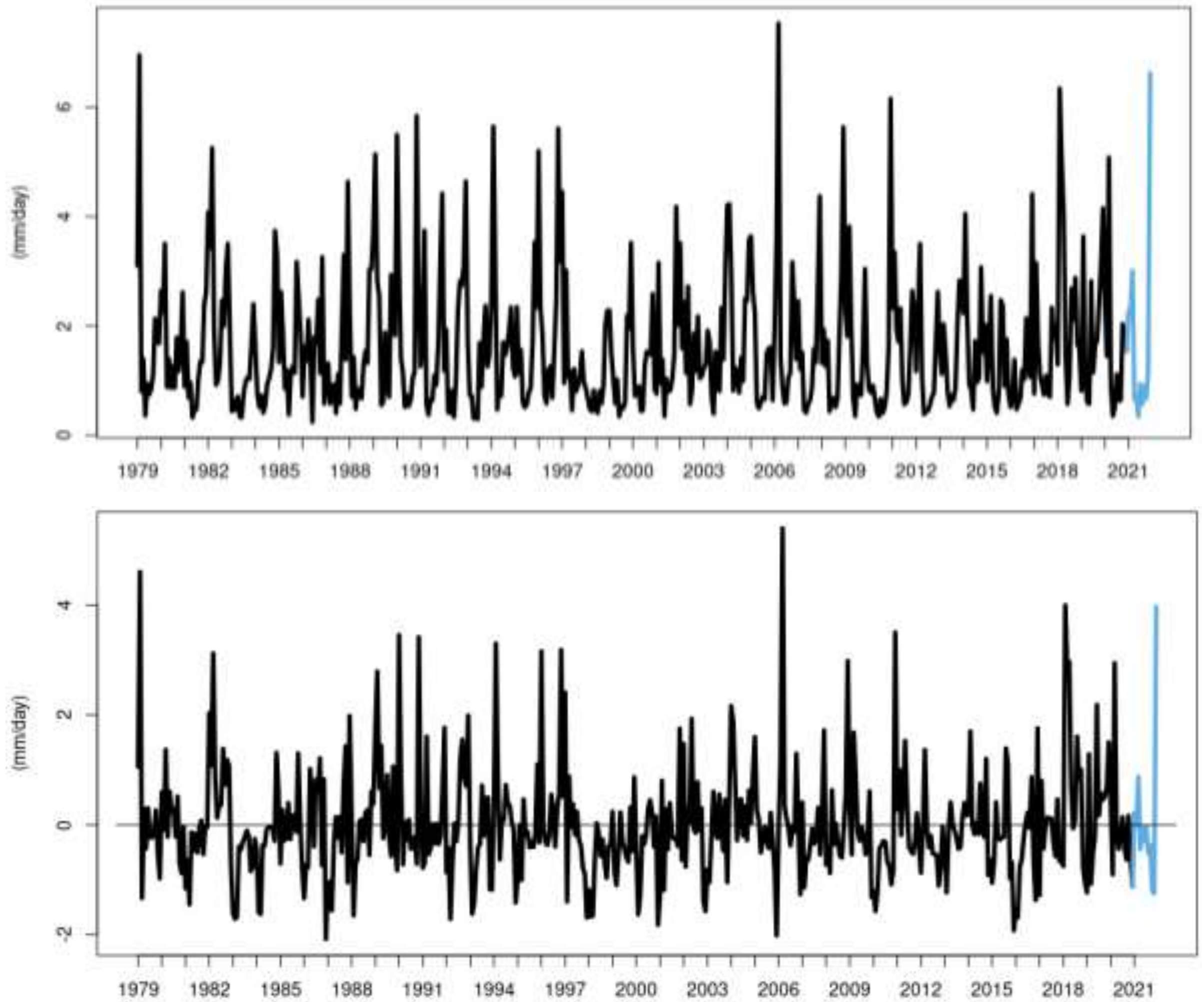

Figure 27. CMAP precipitation (top) and anomaly (bottom) across the MHI Grid with 2021 values in blue

2.7.4.10 Sea Level (Sea Surface Height and Anomaly)

Rationale: Coastal: Rising sea levels can result in a number of coastal impacts, including inundation of infrastructure, increased damage resulting from storm-driven waves and flooding, and saltwater intrusion into freshwater supplies.

Description: Monthly mean sea level time series of local and basin-wide sea surface height and sea surface height anomalies, including extremes.

Timeframe: Monthly.

Region/Location: Observations from selected sites within the Hawaiian Archipelago.

Measurement Platform: Satellite and *in situ* tide gauges.

Sourced from: Aviso (2022), NOAA CoastWatch (2022), and NOAA (2022e).

2.7.4.10.1 Basin-Wide Perspective

This image of the mean sea level anomaly for March 2021 compared to 1993-2016 climatology from satellite altimetry provides a glimpse into the 2021 weak La Niña conditions across the Pacific Basin. The image captures the fact that sea level is higher in the Western Pacific and lower in the Central and Eastern Pacific (this basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow).

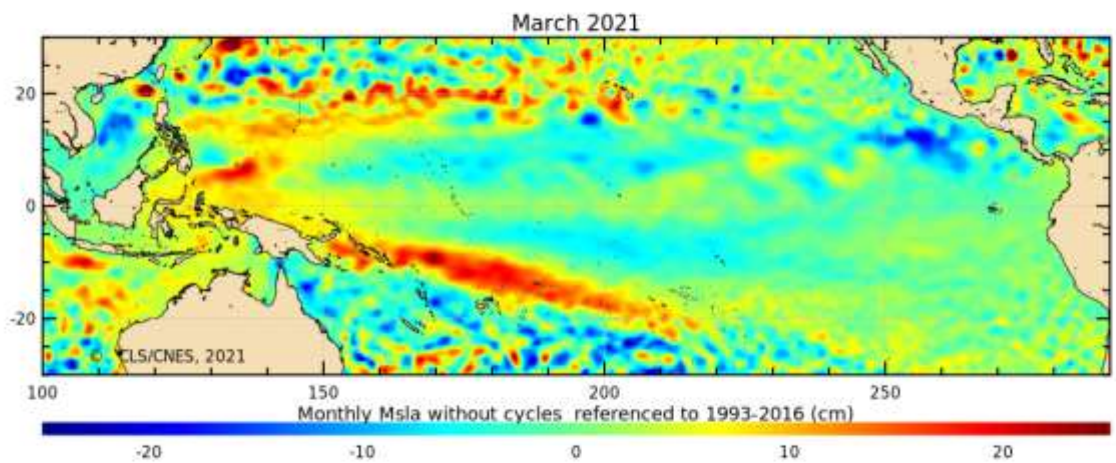

Figure 28a. Sea surface height anomaly

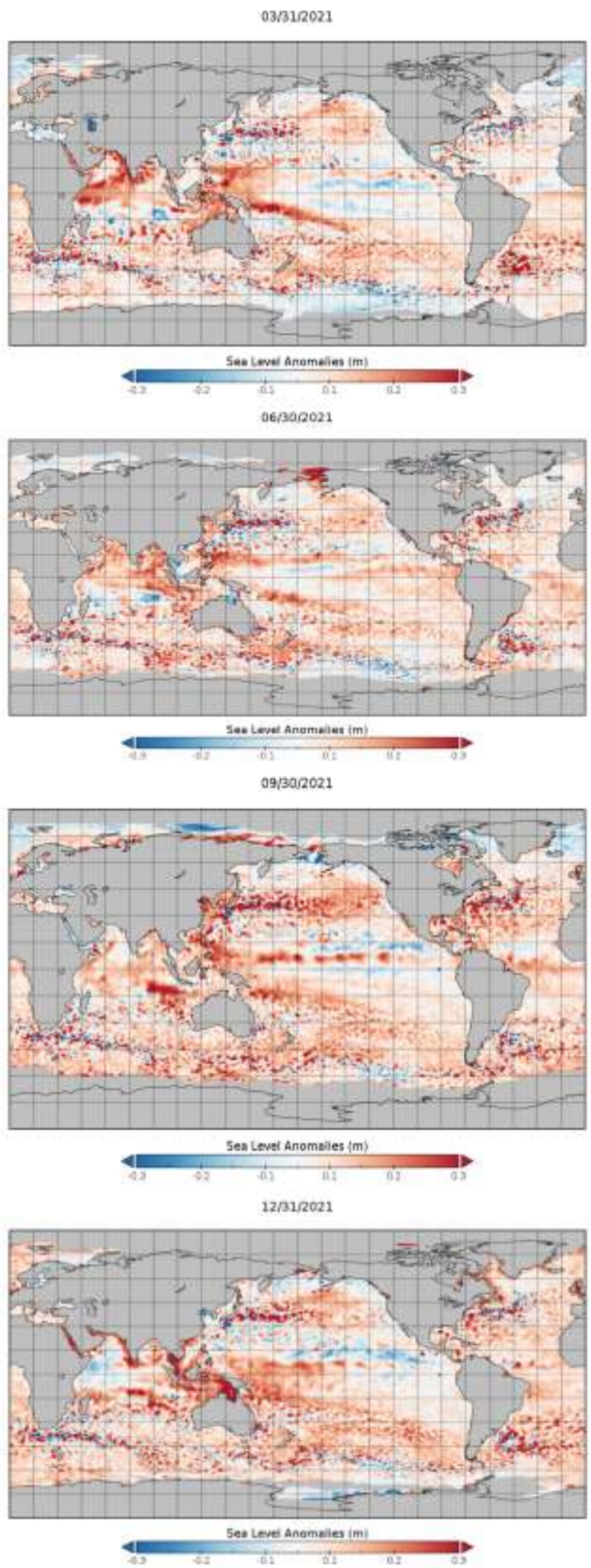

Figure 28b. Quarterly time series of mean sea level anomalies during 2021

Altimetry data are provided by the NOAA Laboratory for Satellite Altimetry, accessed from NOAA CoastWatch (2022).

2.7.4.10.2 Local Sea Level

These time-series from *in situ* tide gauges provide a perspective on sea level trends within each Archipelago (Tide Station Time Series from NOAA Center for Operational Oceanographic Products and Services, or CO-OPS).

The following figures and descriptive paragraphs were inserted from the NOAA Tides and Currents website. Figure 29 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The calculated trends for all stations are available as a table in millimeters/year and in feet/century. If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The relative sea level trend is 1.55 millimeters/year with a 95% confidence interval of +/- 0.21 mm/yr based on monthly mean sea level data from 1905 to 2021 which is equivalent to a change of 0.51 feet in 100 years.

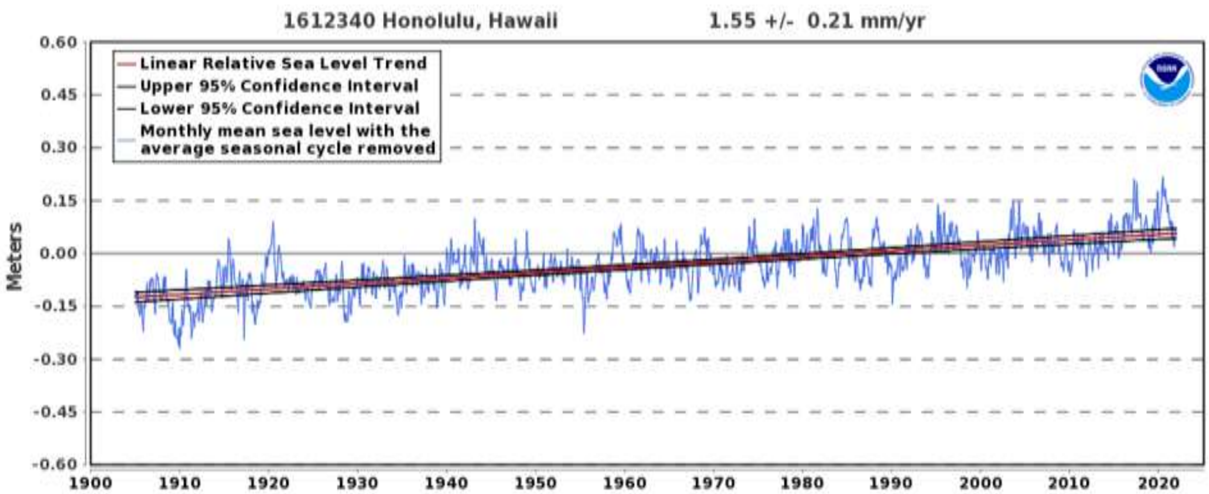

Figure 29. Monthly mean sea level without regular seasonal variability due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents

2.8 ESSENTIAL FISH HABITAT

2.8.1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) includes provisions concerning the identification and conservation of essential fish habitat (EFH) and, under the EFH final rule, habitat areas of particular concern (HAPC) (50 Code of Federal Regulations [CFR] 600.815). The MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." HAPC are those areas of EFH identified pursuant to 50 CFR 600.815(a)(8), and meeting one or more of the following considerations: (1) ecological function provided by the habitat is important; (2) habitat is sensitive to human-induced environmental degradation; (3) development activities are, or will be, stressing the habitat type; or (4) the habitat type is rare.

NMFS and the regional fishery management councils must describe and identify EFH in fishery management plans (FMPs) or fishery ecosystem plans (FEPs), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and State agencies regarding actions that would adversely affect EFH. Councils also have the authority to comment on federal or State agency actions that would adversely affect the habitat, including EFH, of managed species. Fishery management actions must be evaluated for impacts to all EFH and HAPC in the area of effect and not just the EFH and HAPC for the fishery to which the management action applies.

The EFH Final Rule strongly recommends regional fishery management councils and NMFS to conduct a review and revision of the EFH components of FMPs every five years (600.815(a)(10)). The Council's FEPs state that new EFH information should be reviewed, as necessary, during preparation of the annual reports by the Plan Teams. Additionally, the EFH Final Rule states "Councils should report on their review of EFH information as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to §600.315(e)." The habitat portion of the annual SAFE report is designed to meet the FEP requirements and EFH Final Rule guidelines regarding EFH reviews.

National Standard 2 guidelines recommend that the SAFE report summarize the best scientific information available concerning the past, present, and possible future condition of EFH described by the FEPs.

2.8.1.1 EFH Information

The EFH components of FMPs include the description and identification of EFH, lists of prey species and locations for each managed species, and optionally, HAPC. Impact-oriented components of FMPs include federal fishing activities that may adversely affect EFH, non-federal fishing activities that may adversely affect EFH, non-fishing activities that may adversely affect EFH, conservation and enhancement recommendations, and a cumulative impacts analysis on EFH. The last two components include the research and information needs section, which feeds into the Council's Five-Year Research Priorities, and the EFH update procedure, which is described in the FEP but implemented in the annual SAFE report.

The Council has described EFH for five management unit species (MUS) under its management authority, some of which are no longer MUS: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), former coral reef ecosystem (CREMUS), and precious corals (PCMUS). The Hawaii FEP describes EFH for the BMUS, CMUS, and PCMUS.

EFH reviews of the biological components, including the description and identification of EFH, lists of prey species and locations, and HAPC, consist of three to four parts:

- Updated species descriptions, which can be found appended to the SAFE report. These can be used to directly update the FEP;
- Updated EFH levels of information tables, which can be found in this Section 2.8.4;
- Updated research and information needs, which can be found in Section 2.8.5. These can be used to directly update the FEP; and
- An analysis that distinguishes EFH from all potential habitats used by the species, which is the basis for an options paper for the Council. This part is developed if enough information exists to refine EFH.

2.8.1.2 Habitat Objectives of FEP

The habitat objective of the FEP is to refine EFH and minimize impacts to EFH, with the following sub-objectives:

- Review EFH and HAPC designations every five years based on the best available scientific information and update such designations based on the best available scientific information, when available; and
- Identify and prioritize research to assess adverse impacts to EFH and HAPC from fishing (including aquaculture) and non-fishing activities, including, but not limited to, activities that introduce land-based pollution into the marine environment.

The annual report has reviewed the precious coral EFH components, crustacean EFH components, and non-fishing impacts components, resetting the five-year timeline for review. The Council’s support of non-fishing activities research is monitored through the program plan and five-year research priorities, not the annual report.

2.8.1.3 Response to Previous Council Recommendations

At its 172nd meeting in March 2018, the Council recommended that staff develop an omnibus amendment updating the non-fishing impact to EFH sections of the FEPs, incorporating the non-fishing impacts EFH review report by Minton (2017) by reference. An options paper was developed.

At its 173rd meeting in June 2018, the Council directed staff to develop options to redefine EFH precious corals in Hawaii for Council consideration for an FEP amendment. An options paper was developed and presented to the Council.

At its 174th meeting in October 2018, the Council directed staff to prepare an amendment to the Hawaii FEP to revise EFH for precious corals and selected the following preliminarily preferred options for the staff to further analyze revising existing beds and designating new beds as EFH, updating geographic extent and habitat characteristics, and updating the FEPs.

At its 178th meeting in July 2019, the Council approved the draft amendment to the Hawaii FEP to revise precious coral EFH and directed staff to send the document to NMFS PIRO for completion, however, there were issues during the final transmittal associated with the designations of the new precious coral EFH as coral beds.

At its 181st meeting in March 2020, the Council directed staff to continue working with NOAA General Counsel and PIRO Sustainable Fisheries Division on the EFH amendment to ensure its transmittal. Additionally, the Council directed staff to develop options for designating the new EFH areas as precious coral beds under the Hawaii FEP. The action will be reinitiated in 2022.

At its 182nd meeting in June 2020, the Council requested that NMFS work with the Council to determine "non-essential" fish habitat to look at ways to remove areas that are degraded from being considered EFH.

At its 187th meeting in September 2021, the Council recommended that the Chair recommend at the October 2021 CCC meeting that NMFS work with the Council to review EFH guidance in terms of how that guidance requiring the Council to identify and describe how EFH has been applied in the Western Pacific Region.

2.8.2 Habitat Use by MUS and Trends in Habitat Condition

The Hawaiian Archipelago is an island chain in the central North Pacific Ocean. It runs for approximately 1,500 miles in a northwest direction, from Hawaii Island in the southeast to Kure Atoll in the northwest and is among the most isolated island areas in the world. The chain can be divided according to the large and mountainous Main Hawaiian Islands (MHI; Hawaii, Maui, Lanai, Molokai, Kahoolawe, Oahu, Kauai, and Niihau) and the small, low-lying Northwest Hawaiian Islands (NWHI), which include Necker, French Frigate Shoals, Laysan, and Midway atoll. The largest of the MHI is Hawaii Island at just over 4,000 square miles – the largest in Polynesia, while Kahoolawe is the smallest at 44.6 square miles.

The archipelago developed as the Pacific plate moved slowly over a hotspot in the Earth's mantle. Thus, the islands on the northwest end of the archipelago are older; it is estimated that Kure Atoll is approximately 28 million years old while Hawaii Island is approximately 400,000 years old. The highest point in Hawaii is Mauna Kea, at approximately 13,800 feet.

The MHI are all in tropical latitudes. The archipelago becomes subtropical at about French Frigate Shoals (23°46' N). The climate of the Hawaiian Islands is generally tropical, but there is great climactic variation, due primarily to elevation and leeward versus windward areas. Easterly trade winds bring much of the rain, and so the windward sides of all the islands are typically wetter. The south and west (leeward) sides of the islands tend to be drier. Hawaii receives the majority of its precipitation from October to April, while drier conditions generally prevail from May to September. Tropical storms and hurricanes occur in the northern hemisphere hurricane and typhoon season, which runs from June through November.

There is fairly little shallow water habitat in Hawaii, owing to the islands' steep rise from the abyssal deep. However, there are some larger areas, such as Penguin Bank between Oahu and Molokai, which are relatively shallow. Hawaii has extensive coral reef habitat throughout the MHI as they are much younger and have more fringing reef habitat than the NWHI, which has shallower reef habitat overall.

EFH in the Hawaiian Archipelago for the MUS comprises all substrate from the shoreline to the 700 m isobath. The entire water column is described as EFH from the shoreline to the 700 m isobath, and the water column to a depth of 400 m is described as EFH from the 700 m isobath to the limit or boundary of the EEZ (see Figure 30). The coral reef ecosystems surrounding the islands in the MHI and NWHI have been the subject of a comprehensive monitoring program through the PIFSC Coral Reef Ecosystem Division (CRED) biennially since 2002, surveys are focused on the nearshore environments surrounding the islands, atolls, and reefs. PIFSC CRED was replaced by the Coral Reef Ecosystem Program (CREP) within the PIFSC Ecosystem Sciences Division (ESD) before being shifted to the Archipelagic Research Program (ARP).

No new data were collected in 2021 to inform updates of habitat use by MUS or trends in habitat condition. However, derived habitat requirements for larval uku (*Aprion virescens*) were developed to inform statistical species distribution models (SDMs). PIFSC staff analyzed spatiotemporal patterns of uku, a shallow water MUS, from 2010–2019 to explore spatially explicit changes in abundance and distributions and to identify the underlying drivers. The localized density (individuals per 100 square meters) and the center of gravity of the species' distribution in the shallow MHI waters (0–30 m) were estimated with a spatiotemporal generalized linear mixed model that accounts for spatial autocorrelation between spatially-referenced observations and effects of potential environmental drivers (i.e., oceanographic conditions). Changes in *A. virescens* densities were best explained by the combination of static and dynamic surface oceanographic conditions (i.e., density, and surface wind variability, respectively). The conventional model selection indicates that common oceanographic variables such as chlorophyll-a concentration and SST were less useful or unrelated. High variability in the geographic center of gravity of uku within the study region was observed between Oahu and Molokai. The observed shift over time in the center of gravity is not reflective of a uniform shift in densities but localized changes in density around some islands (i.e., Maui and Hawaii). Overall, these findings indicate that considering static variables (i.e., depth) alone is insufficient in projecting spatiotemporal patterns of highly mobile species in this region, and a model that can estimate local trends with spatiotemporal models improved the interpretation of changes to species distribution.

In addition to the EFH modeling work on uku conducted by PIFSC in 2021, the Council supported a similar EFH modeling project for the species (Franklin 2021). Fishery-independent data was applied to boosted regression tree models (i.e., a type of SDM) to define the geographic extent of EFH for sub-adult and adult life stages of uku in the MHI. Separate SDMs were constructed for shallow waters (0–30 m) and deep waters (30–300 m) using NOAA diver survey data and NOAA and University of Hawaii baited stereo-video camera arrays, respectively. For the shallow-water models, the direction that the habitat slope faces, depth, and wave height were strong predictors of uku occurrence. For the deep-water model, depth was the predominant habitat variable. Franklin (2021) also developed maps delineating and categorizing uku EFH based on predicted occurrence. Ultimately, over half of derived uku EFH was classified as "basic EFH", with "hot spots" and "core EFH" representing anywhere from 0 to 2.4%.

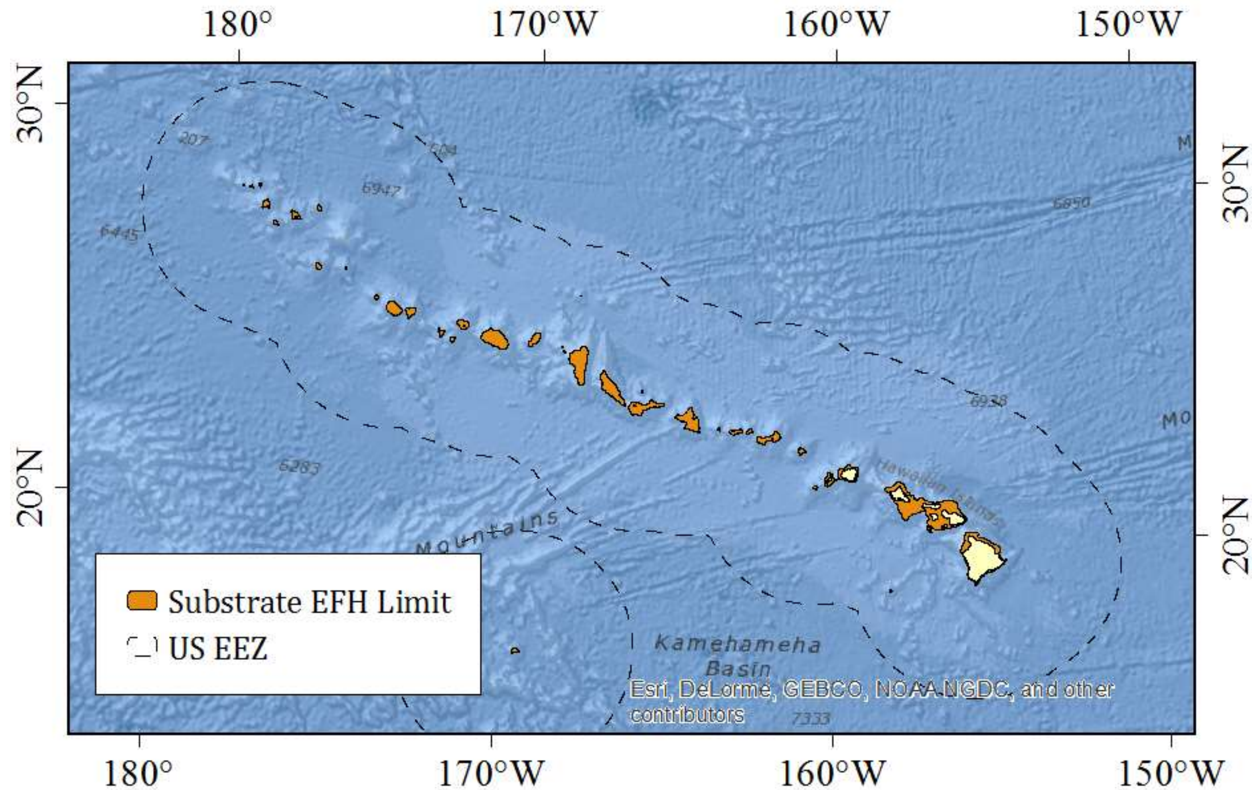

Figure 30. Substrate EFH limit of 700 m isobath around the Hawaiian Archipelago (from GMRT; Ryan et al. 2009)

2.8.2.1 Habitat Mapping

No new habitat mapping was conducted in 2021.

2.8.2.2 Benthic Habitat

EFH for juvenile and adult life stages of Kona crab extends from the shoreline to the 100 m isobath (64 FR 19067, April 19, 1999). All benthic habitat is considered EFH for crustacean species (64 FR 19067, April 19, 1999). Juvenile and adult bottomfish EFH extends from the shoreline to the 400 m isobath (64 FR 19067, April 19, 1999), and juvenile and adult deepwater shrimp habitat extends from the 300m isobath to the 700 m isobath (73 FR 70603, November 21, 2008).

2.8.2.2.1 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae are surveyed as a part of the Pacific Reef Assessment and Monitoring Program (RAMP) led by the PIFSC Ecosystem Sciences Division (ESD). No RAMP field work was conducted in Hawaii in 2021.

2.8.2.3 Oceanography, Water Quality, and Other Environmental Data

The water column is also designated as EFH for selected MUS life stages at various depths. For larval stages of all species except deepwater shrimp, the water column is EFH from the shoreline to the EEZ. Coral reef species egg and larval EFH is to a depth of 100 m; crustaceans, 150m; and bottomfish, 400 m. Please see the Climate and Oceanic Indicator section (Section 2.7) for information related to oceanography and water quality. While no substantial field research data efforts occurred in 2021, satellite and buoy data are continuously collected and archived. PIFSC staff recently developed an advanced data compilation tool, the Environmental Data Summary (EDS), that gives users a simple, consistent way to enhance existing *in situ* observations with external gridded environmental data. The EDS is written in R and provides users an interface to NOAA CoastWatch and OceanWatch datasets through the ERDDAP server protocol. The EDS allows users to download, filter, and/or extract large amounts of gridded and tabular data given user-defined time stamps and geographical coordinates. The various external environmental data summarized at individual survey sites can aid scientists in assessing and understanding how environmental variabilities impact living marine resources. The EDS outputs were summarized at the National Coral Reef Monitoring Program (NCRMP) Rapid Ecological Assessment (REA) site level from 2000 to 2020 across 57 islands covered by the survey. PIFSC is planning to expand the utility of EDS with a broader range of gridded NOAA CoastWatch and OceanWatch data products (e.g., wave, wind) at finer spatiotemporal scales (e.g., water columns). Target data content includes spatial data (e.g., remote sensing), modeled data (e.g., Regional Ocean Modeling Systems), and socioeconomic data, including human density.

2.8.3 Report on Review of EFH Information

There were no EFH reviews for Hawaii completed in 2021. A review of the biological components of crustacean EFH in Guam and Hawaii was finalized in 2019 and can be found in Appendix C of the 2019 reports for the Hawaiian and Mariana Archipelagos (WPRFMC 2020a, WPRFMC 2020b). Non-fishing and cumulative impacts to EFH were reviewed in 2016 through 2017, which can be found in Minton (2017).

2.8.4 EFH Levels

NMFS guidelines codified at 50 C.F.R. § 600.815 recommend Councils organize data used to describe and identify EFH into the following four levels:

- Level 1: Distribution data are available for some or all portions of the geographic range of the species.
- Level 2: Habitat-related densities of the species are available.
- Level 3: Growth, reproduction, or survival rates within habitats are available.
- Level 4: Production rates by habitat are available.

The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a particular managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery.

The Hawaiʻi Undersea Research Laboratory (HURL) is a center operating under the School of Ocean and Earth Sciences and Technology (SOEST) at the University of Hawaiʻi (UH) and NOAA's Office of Ocean Exploration and Research. The unique deep-sea research operation runs the Pisces IV and V manned submersibles and remotely operated vehicles (ROVs) for investigating the undersea environment through hypothesis driven projects that address gaps in knowledge or scientific needs. HURL maintains a comprehensive video database, which includes biological and substrate data extracted from their dive video archives. Submersible and ROV data are collected from depths deeper than 40 m. Observations from the HURL video archives are considered Level 1 EFH information for deeper bottomfish and precious coral species which exist in the database though cannot be considered to observe absence of species. Survey effort is low compared to the range of species observed.

2.8.4.1 Precious Corals

No new data relevant to precious coral EFH were collected in 2021, but the Council is currently in the process of defining new EFH for precious coral MUS (see Section 2.8.1.3). EFH for precious corals was originally designated in Amendment 4 to the Precious Corals FMP (64 FR 19067, April 19, 1999), using the level of data found in Table 59.

Table 59. Level of EFH available for Hawaii precious corals MUS

Species	Pelagic Phase (Larval Stage)	Benthic Phase	Source(s)
Pink Coral (*Corallium*)			
Pleurocorallium secundum (prev. *Corallium secundum)*	0	1	Figueroa and Baco (2014); HURL Database
Hemicorallium laauense (prev. *C. laauense)*	0	1	HURL Database
Gold Coral			
Kulamanamana haumeaae (prev. Gerardia spp.)	0	1	Sinniger et al. (2013); HURL Database
Bamboo Coral			
Acanella spp.	0	1	HURL Database
Black Coral			
Antipathes griggi (prev. *Antipathes dichotoma)*	0	1	Opresko (2009); HURL Database
A. grandis	0	1	HURL Database
Myriopathes ulex (prev. *A. ulex)*	0	1	Opresko (2009); HURL Database

2.8.4.2 Bottomfish and Seamount Groundfish

No new data relevant to bottomfish or seamount groundfish EFH were collected in 2021. EFH for bottomfish and seamount groundfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999). The levels of information presented in Table 60 have not changed. To analyze the potential effects of a proposed fishery management action on EFH, one must consider all designated EFH, but research examining depth and habitat requirements for most species is generally lacking (PIFSC 2021). However, observations from baited cameras in the MHI (limited to 300 m depth) found that *Etelis* spp. are more abundant at 210–300 m and *Pristipomoides* spp. are more abundant at 90–270 m depth (Merritt et al. 2011; Misa et al. 2013). PIFSC (2021) concluded that evidence suggests that *Lethrinidae* spp. peak distribution is shallower than Pristipomoides spp., which is shallower than *Etelis* spp., but there is overlap between these groups.

Table 60. Level of EFH information available for Hawaii bottomfish and seamount groundfish MUS

Life History Stage	Eggs	Larvae	Juvenile	Adult
Aphareus rutilans (red snapper/silvermouth)	0	0	0	1

Life History Stage	Eggs	Larvae	Juvenile	Adult
Aprion virescens (gray snapper/jobfish)	0	0	1	1
Epinephelus quernus (sea bass)	0	0	1	1
Etelis carbunculus (red snapper)	0	0	1	1
E. coruscans (red snapper)	0	0	1	1
Pristipomoides filamentosus (pink snapper)	0	0	1	1
P. sieboldii (pink snapper)	0	0	1	1
P. zonatus (snapper)	0	0	0	1
Beryx splendens (alfonsin)	0	1	2	2
Hyperoglyphe japonica (ratfish/butterfish)	0	0	0	1
Pseudopentaceros richardsoni (armorhead)	0	1	1	3

2.8.4.3 Crustaceans

No new data relevant to crustacean EFH were collected in 2021. EFH for crustaceans was originally designated in Amendment 10 to the Crustaceans FMP (64 FR 19067, April 19, 1999). EFH definitions were also approved for deepwater shrimp through an amendment to the Crustaceans FMP in 2008 (73 FR 70603, November 21, 2008).

Table 61. Level of EFH information available for Hawaii Kona crab

Life History Stage	Eggs	Larvae	Juvenile	Adult
Kona crab (*Ranina ranina*)	1	0	1	1-2

Table 62. EFH and HAPC for Hawaii MUS

MUS	Species Complex	EFH	HAPC
Bottomfish and Seamount Groundfish	**Shallow-water species (0–50 fm):** uku (*Aprion virescens*)	**Eggs and larvae:** the water column extending from the shoreline to the outer limit of the EEZ down to a depth of 400 m (200 fm). **Juvenile/adults:** the water column and all bottom habitat extending from the shoreline to a depth of 400 m (200 fm).	All slopes and escarpments between 40–280 m (20 and 140 fm).

MUS	Species Complex	EFH	HAPC
	Deep-water species (50–200 fm): ehu (*Etelis carbunculus*), onaga (*E. coruscans*), ʻōpakapaka (*Pristipomoides filamentosus*), kalekale (*P. sieboldii*), gindai (*P. zonatus*), hapuʻupuʻu (*Epinephelus quernus*), lehi (*Aphareus rutilans*)	**Eggs and larvae:** the water column extending from the shoreline to the outer limit of the EEZ down to a depth of 400 m (200 fathoms). **Juvenile/adults:** the water column and all bottom habitat extending from the shoreline to a depth of 400 meters (200 fm).	All slopes and escarpments between 40–280 m (20 and 140 fm). Three known areas of juvenile ʻōpakapaka habitat: two off Oahu and one off Molokai.
	Seamount groundfish species (50–200 fm): armorhead (*Pentaceros wheeleri*), ratfish/butterfish (*Hyperoglyphe japonica*), alfonsin (*Beryx splendens*)	**Eggs and larvae:** the (epipelagic zone) water column down to a depth of 200 m (100 fm) of all EEZ waters bounded by latitude 29°–35°. **Juvenile/adults:** all EEZ waters and bottom habitat bounded by latitude 29°–35° N and longitude 171° E–179° W between 200 and 600 m (100 and 300 fm).	No HAPC designated for seamount groundfish.
Crustaceans	Kona crab (*Ranina ranina*)	**Eggs and larvae:** the water column from the shoreline to the outer limit of the EEZ down to a depth of 150 m (75 fm). **Juvenile/adults:** all of the bottom habitat from the shoreline to a depth of 100 m (50 fm).	All banks in the NWHI with summits less than or equal to 30 m (15 fathoms) from the surface.

MUS	Species Complex	EFH	HAPC
	Deepwater shrimp (*Heterocarpus* spp.)	**Eggs and larvae:** the water column and associated outer reef slopes between 550 and 700 m. **Juvenile/adults:** the outer reef slopes at depths between 300-700 m.	No HAPC designated for deepwater shrimp.
Precious Corals	**Deep-water precious corals (150–750 fm):** Pink coral (*Pleurocorallium secundum*), red coral (*Hemicorallium laauense*), gold coral (*Kulamanamana haumeaae*), bamboo coral (*Acanella* spp.) **Shallow-water precious corals (10-50 fm):** Black coral (*Antipathes griggi*), black coral (*Antipathes grandis*), black coral (*Myriopathes ulex*)	EFH for precious corals is confined to six known precious coral beds located off Keāhole Point, Makapu‘u, Ka‘ena Point, Wespac bed, Brooks Bank, and 180 Fathom Bank. EFH has also been designated for three beds known for black corals in the MHI between Milolii and South Point on the Big Island, the ‘Au‘au Channel, and the southern border of Kauai.	Includes the Makapu‘u bed, Wespac bed, Brooks Banks bed. For black corals, the ‘Au‘au Channel has been identified as HAPC.

Source: WPRFMC (2009).

2.8.5 Ongoing Projects

2.8.5.1 Enhancing reef resilience through process investigations

This project is a set of process investigations focused on revealing differential resilience to habitat stressors by describing interacting trends in coral populations, reef structure, and their ecological and physical forcing. In 2020, this project included improving quality control and access to environmental data collected by the coral program over the last 20 years, and in future years will examine reef-scale coral cover change, drivers of juvenile coral density, drivers of change in reef structure, drivers of complexity, carbonate budgets, and *in-situ* temperatures relative to benthic changes. Efforts are beginning to link habitat structural complexity/rugosity (quantified from Structure-from-Motion models across the MHI) to fish composition and abundance. This work is ongoing.

2.8.5.2 Assessing impacts of Hawaii's 2019 coral bleaching event on coral recovery

Research is being conducted to identify which reefs and coral taxa in Hawaii are especially resilient to bleaching and what the potential long term impacts of bleaching are at the colony and reef-level by identifying resilient coral communities following multiple bleaching events, automating bleaching quantification, and tracking colonies over time to investigate growth and mortality in years prior, during, and following bleaching. This work is ongoing.

2.8.5.3 Understanding importance of nearshore habitats for MUS

The primary goal of this research is to refine the understanding of how inshore habitats, including coral reefs, contribute to the productivity of MUS fisheries and/or ESA listed species, focusing particularly on those MUS that are primarily caught in federal waters and certain key coral reef fishes that are classified as ECS. The quantitative information linking offshore and nearshore habitats can be applied to the Council's efforts to refine existing BMUS designations. Most of these nearshore and laboratory research efforts are designed to bridge a key life history stage data gap, and feed into an essential fish habitat modeling effort described later.

Another project is assessing larval uku (*Aprion virescens*) habitat use in nearshore and offshore of Hawaii. Uku is the only shallow bottomfish stock in Hawaii within the BMUS complex. EFH for uku is currently broadly designated from the shoreline to offshore down to 240 meters deep, and more information is needed on connectivity from offshore to nearshore to refine EFH designations. This study will assess uku habitat and prey base utilization in nearshore and offshore ecosystems. This effort will include lab work for processing (i.e., sorting, identifying, and measuring) larval uku from a backlog of existing wet-archived ichthyoplankton samples from nearshore and offshore ecosystems along Oahu and Hawaii Island. Through this work, PIFSC plans to quantify the connectivity of uku from offshore to nearshore, including the presence/absence of larval uku in the nearshore coral reef ecosystem, to assist with potential future habitat models and refining Hawaii EFH and HAPC. Though hampered by the COVID restrictions, this work has continued and results should be finalized in 2022.

Derived habitat requirements for larval uku will be used to inform statistical species distribution models (SDMs). The fitted SDMs will be coupled with spatially and temporally resolved hydrographic and oceanographic reanalysis derived from three-dimensional Regional Ocean Modeling System (ROMS). The ROMs-SDMs outputs can be used to evaluate spatiotemporal trends in boundaries delineating larval uku habitat in key nearshore management areas. Further development of a generalized statistical species distribution modeling framework that will be useful for predicting distributional responses of reef fish species and other archipelagic fishes to environmental variabilities is continuing. The modeling framework uses Tweedie Generalized Additive Models (GAM) to quantify association among size-specific reef fish biomass and relevant environmental variables (e.g., SST, chl-*a*, salinity, depth). GAMs are fitted to PIFSC survey data that encompasses 44 islands across the Western Pacific region and include ~500 species. Fitted GAMs are coupled with either the remotely-sensed environmental data (e.g., OceanWatch and CoastWatch) or the output from regional circulation models (e.g., ROMS) to determine reef fish distributions at various spatial scales. The model outputs can be used to evaluate spatiotemporal trends in boundaries delineating EFH for each species. The model results should contribute to Council determinations on how best to manage ECS. Additionally, a report stemming from the collaboration between the Council and researchers at the University of Hawaii was recently released (Franklin 2021).

2.8.5.4 Predicting the impacts of climate change on ‘opelu koas

Koas are temporally and spatially ephemeral habitats for ‘opelu (*Decapterus macarellus*), also known as the mackerel scad. The ‘opelu koa work will explore the environmental factors that characterize these aggregation sites, as well as what drives CPUE, abundance, and catchability. ‘Opelu are important forage species in the coastal pelagic ecosystem and are an important fishery in Hawai‘i. To further investigate what factors may drive changes in catch, compilation of remotely sensed and modeled data products, small-boat field surveys, and interviews will be conducted with ‘opelu fishermen since there is a long history of ‘opelu fishing in Hawaii. Information from the fishermen interviews will assist in parameterizing the field work planned for 2021. Koas serve as an important subset of the overall pelagic habitat for ‘opelu, and this work will further the understanding of the definition, function, and criticalities of these small areas for this species. This work was interrupted by the COVID-19 pandemic but is ongoing.

2.8.5.5 Bottomfish fishery independent surveys (BFISH)

Annual bottomfish surveys were successfully conducted in 2021 despite the COVID-19 pandemic. The BFISH survey collects species-specific abundance information on key Deep-7 species throughout the MHI. Habitat data, including depth, temperature, and seafloor type, are also collected. The 2021 BFISH effort expanded from 500 to 750 survey grids to investigate optimal sampling intensity with respect to specific precision targets. The 2021 survey effort also expanded detailed temperature/depth sampling by incorporating temperature/depth recorders on hook-and-line sampling gear in addition to previously instrumented camera gear. This information can be used to inform and refine existing Deep-7 EFH through methods outlined by Oyafuso et al. (2017) and Moore et al. (2013). A quarterly report on this monitoring can be found at Ault and Smith (2020). In 2022, additional efforts will focus on refined species-distribution modeling for Hawaii Deep-7 bottomfish species.

2.8.6 Research and Information Needs

Based, in part, on the information provided in the tables above the Council identified the following scientific data which are needed to more effectively address the EFH provisions:

2.8.6.1 All FMP Fisheries

- Distribution of early life history stages (eggs and larvae) of MUS by habitat.
- Juvenile habitat (including physical, chemical, and biological features that determine suitable juvenile habitat).
- Food habits (feeding depth, major prey species etc.).
- Habitat-related densities for all MUS life history stages.
- Growth, reproduction, and survival rates for MUS within habitats.

2.8.6.2 Bottomfish Fishery

- Inventory of marine habitats in the EEZ of the Western Pacific region.
- Data to obtain a better SPR estimate for American Samoa’s bottomfish complex.
- Baseline (virgin stock) parameters (CPUE, percent immature) for the Guam/NMI deep-water and shallow water bottomfish complexes.
- High resolution maps of bottom topography/currents/water masses/primary productivity.

- Habitat utilization patterns for different life history stages and species.

2.8.6.3 Crustaceans Fishery

- Identification of post-larval settlement habitat of all CMUS.
- Identification of "source/sink" relationships in the NWHI and other regions (i.e., relationships between spawning sites settlement using circulation models, genetic techniques, etc.).
- Establish baseline parameters (CPUE) for the Guam/Northern Marinas crustacean populations.
- Research to determine habitat related densities for all CMUS life history stages in American Samoa, Guam, Hawaii, and CNMI.
- High resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, and habitat relief.

2.8.6.4 Precious Coral Fishery

- Statistically sound estimates of distribution, abundance, and condition of precious corals throughout the MHI. Targeted surveys of areas that meet the depth and hardness criteria could provide very accurate estimates.
- Environmental conditions necessary for precious coral settlement, growth, and reproduction. The same surveys used for abundance and distribution could collect these data as well.
- Quantitative measures of growth and productivity.
- Taxonomic investigations to ascertain if the *H. laauense* that is commonly observed between 200- and 600-meters depth is the same species as those *H. laauense* observed below 1,000 meters in depth.
- Continuous backscatter or LIDAR data in depths shallower than 60 m.

2.9 MARINE PLANNING

2.9.1 Introduction

Marine planning is a science-based management tool being utilized regionally, nationally, and globally to identify and address issues of multiple human uses, ecosystem health, and cumulative impacts in the coastal and ocean environment. Efforts by the Western Pacific Regional Fishery Management Council (the Council) to formalize incorporation of marine planning in its actions began in response to Executive Order (EO) 13547, *Stewardship of the Ocean, Our Coasts, and the Great Lakes*. EO 13158, *Marine Protected Areas*, proposes that agencies strengthen the management, protection, and conservation of existing marine protected areas (MPAs), develop a national system of MPAs representing diverse ecosystems, and avoid causing harm to MPAs through federal activities. MPAs, or marine managed areas (MMAs), are one tool used in fisheries management and marine planning.

At its 165th meeting in March 2016, in Honolulu, Hawaii, the Council approved the following objective for the FEPs: To consider the implications of spatial management arrangements in Council decision-making. The following sub-objectives apply:

- Identify and prioritize research that examines the positive and negative consequences of areas that restrict or prohibit fishing to fisheries, fishery ecosystems, and fishermen, such as the Bottomfish Restricted Fishing Areas (BRFAs), military installations, NWHI restrictions, and Marine Life Conservation Districts (MLCDs).
- Establish effective spatially based fishing zones.
- Consider modifying or removing spatial-based fishing restrictions that are no longer necessary or effective in meeting their management objectives.
- As needed, periodically evaluate the management effectiveness of existing spatial-based fishing zones in federal waters.

To monitor implementation of this objective, this annual report includes the Council’s spatially based fishing restrictions and MMAs, the goals associated with those, and the most recent evaluation. Council research needs are not tracked in this report.

To meet the EFH and National Environmental Policy Act (NEPA) mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council and incidents and facilities that may contribute to cumulative impact. The National Marine Fisheries Service (NMFS) is responsible for NEPA compliance, and the Council must assess the environmental effects of ocean activities for the EFH cumulative impacts section of the FEP.

2.9.2 Response to Previous Council Recommendations

There are no standing Council recommendations indicating review deadlines for Hawaii MMAs.

2.9.3 Marine Managed Areas Established Under FEPs

Council-established MMAs were compiled in Table 63 from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. Regulated fishing areas of Hawaii, including the Papahānaumokuākea Marine National Monument, are shown in Figure 31.

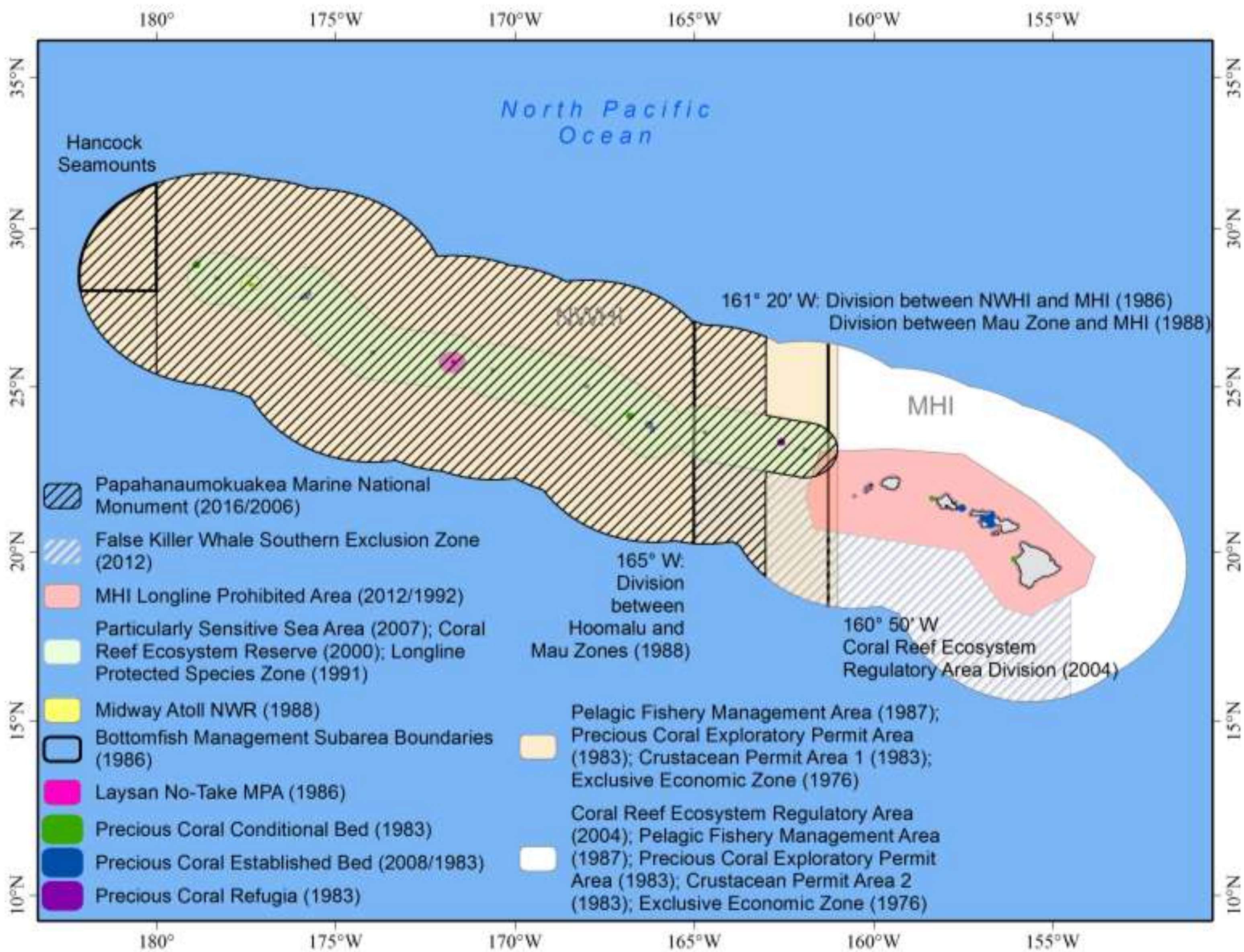

Figure 31. Regulated fishing areas of the Hawaii Archipelago

Table 63. MMAs established under FEP from 50 CFR § 665

Name	FEP	Island	50 CFR/FR/ Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Pelagic Restrictions								
NWHI Longline Protected Species Zone	Pelagic (Hawaii)	NWHI	665.806(a)(1) 56 FR 52214 76 FR 37288 Pelagic FMP Am. 3	351,514.0	Longline fishing prohibited	Prevent longline interaction with monk seals	1991	-
MHI Longline Prohibited Area	Pelagic (Hawaii)	MHI	665.806(a)(2) 57 FR 7661 77 FR 71286 Pelagic FMP Am. 5	248,682.4	Longline fishing prohibited	Prevent gear conflicts between longline vessels and troll/handline vessels	1992	-
Bottomfish Restrictions								
Hancock Seamounts Ecosystem Management Area (HSEMA)	Hawaii Archipelago	NW of Midway Island	HSEMA: 665.209 75 FR 52921 84 FR 2772 Moratorium: 51 FR 27413 Bottomfish FMP	60,826.8	Moratorium	The intent of the continued moratorium is to facilitate rebuilding of the armorhead stock, and the intent of the ecosystem management area is to facilitate research on armorhead and other seamount groundfish	2010	-
Precious Coral Permit Areas								
Keāhole Point	Hawaii Archipelago	Hawaii Island	665.261(2)(i) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	2.7	Fishing by permit only	Manage harvest	2008	-
Ka‘ena Point	Hawaii Archipelago	Oahu	665.261(2)(ii) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	2.7	Fishing by permit only	Manage harvest	2008	-
Makapu‘u	Hawaii Archipelago	Oahu	665.261(1)(i) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	43.15	Fishing by permit only	Manage harvest	2008	-
Brooks Bank	Hawaii Archipelago	NWHI	665.261(2)(iii) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	43.15	Fishing by permit only	Manage harvest	2008	-
180 Fathom Bank	Hawaii Archipelago	NWHI	665.261(2)(iv) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	43.15	Fishing by permit only	Manage harvest	2008	-

Name	FEP	Island	50 CFR/FR/ Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Westpac Bed	Hawaii Archipelago	NWHI	665.261(3) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	43.15	Fishing prohibited	Manage harvest	2008	-
‘Au‘au Channel	Hawaii Archipelago	Maui Nui	665.261(1)(ii) 73 FR 47098 84 FR 2773 Precious Corals FMP Am. 7	728.42	Fishing by permit only	Harvest quota for black coral of 5,000 kg every two years for federal and State waters	2008	-

2.9.4 Fishing Activities and Facilities

2.9.4.1 Aquaculture Facilities

Hawaii has one offshore aquaculture facility recently operational in federal waters that was owned by Ocean Era (formerly Kampachi Farms), but the associated Special Coral Reef Ecosystem Fishing Permit (SCREFP) was transferred to Forever Oceans (see Table 64). A new nearshore aquaculture operation in the waters off of Ewa Beach, Oahu, by Ocean Era is currently in the pre-consultation stage, and a preliminary environmental review was made to resource management agencies for evaluation in March 2021. The aquaculture farm will be situated off of Ewa Beach, Oahu, and will aim to cultivate nenue (*Kyphosus vaigiensis*), moi (*Polydactylus sexifilis*), ogo (*Gracilari* sp.), *Sargassum*, and sea grapes (*Caulerpa* sp.).

Table 64. Offshore aquaculture facilities in Hawaii

Name	Size	Location	Species	Status
Forever Oceans, transferred from Ocean Era (formerly Kampachi Farms)	Shape: Cylindrical Height: 33 ft. Diameter: 39 ft. Volume: 36,600 ft^3	5.5 nautical miles (nm) west of Keauhou Bay and 7 nm south-southwest of Kailua Bay, off the west coast of Hawaii Island 19° 33’ N, 156° 04’ W. Mooring scope is 10,400-foot radius.	*Seriola rivoliana*	On July 6, 2016, NMFS authorized SCREFP for culture and harvest of 30,000 kampachi over two years on July 6, 2016. Array broke loose from mooring and net pen sank in 12,000 feet of water on Dec. 12, 2016. The mooring was redeployed under guidance from the U.S. Army Corps of Engineers (USACE) in late 2018 and stocked with a cohort of 10,000 fish in early 2019. On March 30, 2017, NMFS authorized transfer of the two-year SCREFP from Ocean Era to Forever Oceans. Forever Oceans’ most recent SCREFP expired in December 2021, and there are currently no ongoing, in-water operations.

Additionally, the draft Programmatic Environmental Impact Statement (DPEIS) for an aquaculture management program in the Pacific Islands was published in 2021. Once the DPEIS is finalized, the Council can amend their FEPs to create a permitting program for offshore aquaculture. Relatedly, the State of Hawaii is interested in developing a pre-permitted demonstration/pilot area for offshore aquaculture technologies at their NELHA facility.

2.9.5 Non-Fishing Activities and Facilities

The following section includes activities or facilities associated with known uses and predicted future uses. The Plan Team will update this section as new facilities are proposed and/or built. Due to the sheer volume of ocean activities and the annual frequency of this report, only major activities on multi-year planning cycles are tracked. Activities which are no longer reasonably foreseeable or have been replaced with another planning activity are removed from the report, though may occur in previous reports.

2.9.5.1 Alternative Energy Facilities

Hawaii previously had four proposed wind energy facilities of commercial interest nominated by the Bureau of Ocean Energy Management (BOEM) in its Call Areas northwest and south of Oahu, all of which were in the area identification and environmental assessment stage of the leasing process (Progression Energy 2015), but these projects were disengaged around 2018 (BOEM Hawaii Activities). In December 2020, BOEM put out a new call for recommendations on environmental studies regarding offshore wind facilities, and the Hawaii State Energy Office is facilitating and providing input on studies that could be conducted to mitigate impacts on various resources, including aquatic. In October 2021, the National Renewable Energy Laboratory published a study providing estimates of the Levelized Cost of Energy of offshore wind in the region surrounding Oahu and investigates related topics relevant to planning for offshore wind (Shields et al. 2021). There are several other alternative energy projects also being tracked in this report (Table 65).

Table 65. Alternative energy facilities and development offshore of Hawaii

Name	Type	Location	Impact to Fisheries	Stage of Development	Source
Makai Ocean Engineering, Inc., Natural Energy Laboratory of Hawaii Authority (NELHA)	120 kW Ocean Thermal Energy Conversion (OTEC) Test Site/ 1 MW OTEC Test Site	Ke'ahole, North Kona, West Hawaii	Intake	120 kW OTEC operational; Final EA for 1 MW OTEC Site using existing infrastructure submitted July 2012 and finalizing lease negotiations currently; HEPA Exemption List memo Dec. 27, 2016.	NELHA Energy Projects Final Environmental Assessment, NELHA, July 2012
Honolulu Sea Water Air Conditioning (SWAC)	SWAC	4 miles S of Kaka'ako, Oahu	Benthic impacts; intake	USACE Record of Decision (ROD) signed in 2015. In 2018, HSWAC and the State of Hawaii finalized an agreement to provide seawater air conditioning for eight State buildings. Construction was planned to start in late 2019 or, but the operation was shut	Final Environmental Assessment, June 2014 West Hawaii Today

Name	Type	Location	Impact to Fisheries	Stage of Development	Source
				down in late 2020 due to increasing costs.	
Marine Corps Base Hawaii Wave Energy Test Site (WETS)	Shallow- and Deep-Water Wave Energy	1, 2 and 2.5 km N of Mokapu, Oahu	Hazard to navigation	Shallow and deep water wave energy units operational starting mid-2015. In 2021, deployments were planned for the C-Power 2 kW SeaRay, the Oscilla Triton-C, and the Ocean Energy 500 kW OE35.	Final Environmental Assessment, NAVFAC PAC, January 2014 Tethys The Maritime Executive

2.9.5.2 Military Training and Testing Activities and Impacts

The Department of Defense (DOD) major planning activities in the region are summarized in Table 66.

Table 66. Military training and testing activities offshore of Hawaii

Action	Description	Phase	Impacts
Rim of the Pacific (RIMPAC) Exercise	Multinational, sea control/power projection fleet exercise that has been performed biennially and is currently headquartered in Pearl Harbor, Hawaii. RIMPAC exercise locations are present throughout the State of Hawaii.	RIMPAC Programmatic EA developed in 2002 and a Supplemental Programmatic EA was finalized in 2006 (71 FR 31170). Biennial exercises continue through the present, with the most recent occurring in August 2020 as an at-sea-only event. RIMPAC will occur again in Summer 2022 and will be more traditional.	Programmatic Environmental Assessment, June 2002 U.S. Pacific Fleet
Hawaii-Southern California Training and Testing (HSTT)	Increased naval testing and training activities, including the use of active sonar and explosives	Record of Decision (ROD) available in December 2018 to conduct training and testing activities as identified in Alternative 1 of the HSTT Final Environmental Impact Statement (EIS)/Overseas EIS (OEIS) published in October 2018 (83 FR 66255). NMFS implemented regulations regarding to the incidental take of marine mammals in the HSTT area in July 2020 (85 FR 41780).	The 2018 HSTT EIS/OEIS predicts impacts to access and habitat impact similar to previous analysis in the 2013 HSTT EIS/OEIS.
Long Range Strike Weapon Systems Evaluation Program (WSEP)	Conduct operational evaluations of Long-Range Strike weapons and other munitions as part of Long-Range Strike WSEP operations	Comment period closed Feb. 6, 2017, and final rule on Aug. 22, 2017, for NMFS authorization to take marine mammals incidental to conducting munitions testing	Access – closures during training. Final Environmental Assessment October 2016

Action	Description	Phase	Impacts
	at the Pacific Missile Range Facility at Kauai, Hawaii.	for their Long-Range Strike Weapons Systems Evaluation Program (LRS WSEP) over the course of five years, from August 21, 2017 through August 22, 2022 (82 FR 1702; 82 FR 39684).	NMFS Biological Opinion August 2017
Naval Special Operations Training in the State of Hawaii	Small-unit maritime training activities for naval special operations personnel.	Draft EA released in October 2018. Public comment period through Dec. 10, 2018 was extended to Jan. 7, 2019. Final EA released May 2021.	Access. Draft Environmental Assessment 2018 Final Environmental Assessment 2021

2.9.6 Additional Considerations

2.9.6.1 State of Hawaii Initiatives

The State of Hawaii has several initiatives ongoing, including its 30x30 Initiative and its Ocean Resource Management Plan, which was most recently updated in 2020 (Hawaii Office of Planning 2020). Interested parties are encouraged to provide input to and track the progress of these plans.

2.9.6.2 Bottomfish Restricted Fishing Areas (BRFAs)

In 1997, in response to a federal stock assessment indicating that certain species of the MHI bottomfish stock complex were in danger of being overfished, DAR developed a bottomfish management plan, which included the creation of 19 bottomfish restricted fishing areas (BRFAs) where bottomfish fishing was prohibited. These BRFAs were enacted in 1998. The MHI BRFAs are situated in both State and federal waters. Upon review in 2005, it was determined that the BRFA system did not protect an adequate amount of preferred habitat for bottomfish, so a new system was created in 2007 with 12 BRFAs (Figure 32) with the objective of reducing fishing mortality of MHI bottomfish stocks, rebuilding bottomfish populations on habitats within the BRFAs, and improving bottomfish populations in adjacent fishing areas (Drazen et al. 2014). In 2019, four of the 12 BRFAs were opened: BRFA C (Poipu, Kauai), BRFA F (Penguin Banks), BRFA J (Hana, Maui), and BRFA L (Leleiwi, Hawaii Island) (Figure 32).

On February 25, 2022, the Hawaii Board of Land and Natural Resources (BLNR) approved the reopening of all BRFAs such that registered bottomfish vessels are now allowed to fish for Deep-7 bottomfish in all previously closed BRFAs. During deliberations, representatives from DAR suggested that, because the Deep-7 bottomfish complex is being fished at sustainable levels according to the 2021 stock assessment update (Syslo et al. 2021), DAR is comfortable in taking an adaptive management approach to co-management of the Hawaii bottomfish fishery by opening the BRFAs and relying on other existing conservation and management measures to sustain the fishery.

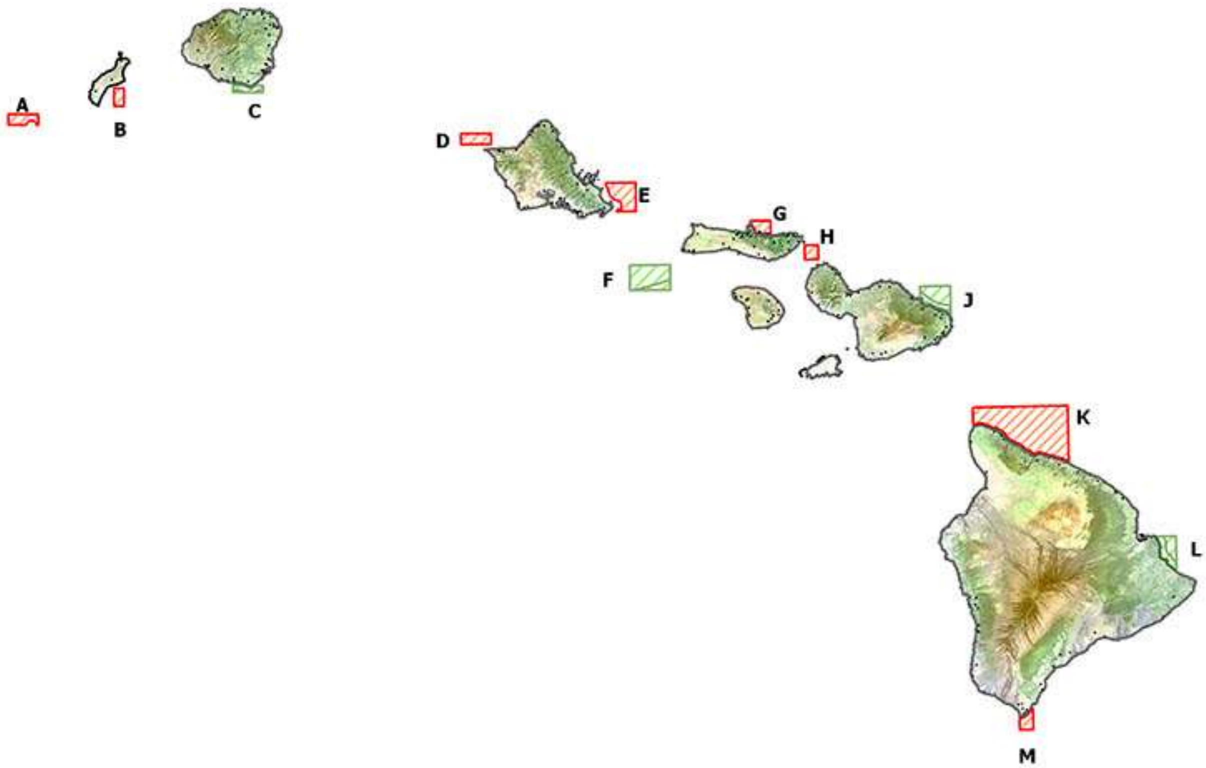

Figure 32. Map of the 12 BRFAs around the MHI; green boxes indicate those areas were opened to bottomfish fishing in 2019 and red boxes indicate areas that remained closed to bottomfish fishing at this time. All BRFAs are now open (from DAR 2021)

3 DATA INTEGRATION

3.1 INTRODUCTION

3.1.1 Potential Indicators for Insular Fisheries

The purpose of this section of the annual Stock Assessment and Fishery Evaluation (SAFE) report is to identify and evaluate potential fishery ecosystem relationships between fishery parameters and ecosystem variables to assess how changes in the ecosystem affect fisheries in the Main Hawaiian Islands (MHI) and across the Western Pacific region. Fishery ecosystem relationships are those associations between various fishery-dependent data measures (e.g., catch, catch-per-unit-effort [CPUE]) and other environmental attributes (e.g., wind, sea surface temperature [SST], currents, etc.) that may contribute to observed trends or act as potential indicators of the status of prominent stocks in the fishery. These analyses represent a first step in a sequence of exploratory analyses that will be utilized to inform new assessments of in determining ecological factors that may be useful to monitor in the context of ecosystem-based fisheries management going forward.

In late 2016, staff from the Council, National Marine Fisheries Service (NMFS), Pacific Islands Fisheries Science Center (PIFSC), Pacific Islands Regional Offices (PIRO), and other fishery resource professionals held a SAFE Report Data Integration Workshop to identify potential fishery ecosystem relationships relevant to local policy in the Western Pacific region and determine appropriate methods to analyze them. Among the ranked potential relationships were bottomfish catch/CPUE and eddy features as well as bottomfish catch/CPUE and surface current, speed, and direction. This chapter reflects exploratory analyses in search of these potential fishery ecosystem relationships.

For the 2017 report, exploratory analyses were performed comparing coral reef fishery species data in the Western Pacific with precipitation, primary productivity, and SST. The Archipelagic Fishery Ecosystem Plan (FEP) Team (Plan Team) suggested several improvements to implement to the initial evaluation, which are reflected in the following preliminary analysis for uku first presented in the 2018 report. The results are prefaced by the Plan Team recommendations for ongoing development and improvement of the Data Integration chapter. Then, the chapter includes brief descriptions of past work on fishery ecosystem relationship assessment in the U.S. Western Pacific, followed by initial evaluations of relationships between uku and ENSO as well as surface zonal currents. The evaluations completed were exploratory in nature and were used as initial analyses to know which comparisons may hold more utility going forward. In subsequent years, this chapter will be updated with analyses through the SAFE report process to include more of the described climate change indicators from Section 2.7.4, and as the strength of certain fishery ecosystem relationships relevant to advancing ecosystem-based fishery management are determined.

3.1.2 Plan Team Recommendations for Section Development

At the Plan Team meeting held on April 30th and May 1st, 2018, participants were presented preliminary data integration results on comparisons between coral reef species and various climate indicators. The Plan Team provided detailed recommendations to support the ongoing development of the data integration section of the Archipelagic annual SAFE report. These suggestions, both general and specific, will continue to be implemented in the coming years to ensure that more refined analyses comprise the data integration section.

Plan Team participants recommended that:

- CPUE data should be standardized and calculated in a more robust fashion, measuring the average catch per unit effort rate over the course of a year to analyze variance.
- Analyses of fishery performance data against environmental variables should focus on dominant gear types rather than the entirety of the fishery or other gear aggregates;
- There should be additional phase lag implemented in the analyses;
- Local knowledge of fishery dynamics, especially pertaining to shifting gear preferences, should be utilized. Changes in dynamics that may have impacted observed fishery trends over the course of available time series, both discreetly and long-term for taxa-specific and general changes should be emphasized; and
- Spatial specificity and precision should be increased for analyses of environmental variables in relation to areas commonly fished.

The analyses presented in this chapter reflect a thoughtful re-approaching to data integration evaluations. Data from 2002 to 2012 were utilized because all data products had consistent coverage within this range. Additional data can be added to either time series as they are made available. Moving forward, incorporating Plan Team recommendations into the annual SAFE report will mark the beginning of a standardized process to implement current data integration analyses on an annual basis. Doing so will promote more proactive management action with respect to ecosystem-based fishery management objectives.

3.1.3 Background Information

Fishery Ecosystem Relationships

There is growing concern that the effects of increased variability in environmental and ecological parameters attributed to climate change may impact fish stocks and the fisheries that harvest them. A recent meta-analysis looking at 235 populations of 124 species of fish nationwide recently suggested that the maximum sustainable yield of fish species has generally declined over the last 80 years in response to ocean warming (Free et al. 2019). In addition to impacts from gradual warming, changes in storm frequency and intensity associated with climate change also threaten fisheries worldwide by disrupting fishing effort and infrastructure of coastal communities, and these impacts are likely to be realized in a more immediate manner (Sainsbury et al. 2018).

In response to elevated awareness of potential impacts to fish stocks and their associated fisheries, there have been increased efforts by scientific researchers to understand how a changing environment may influence commercially important fishery species. Richards et al. (2012) performed a study on a range of environmental factors that could potentially affect the distribution of large-bodied coral reef fish in Mariana Archipelago. Large-bodied reef fish were determined to typically be at the greatest risk of overfishing, and their distribution in the region was shown to be negatively associated with human population density. Additionally, depth, sea surface temperature (SST), and distance to deepwater were identified as important environmental factors to large-bodied coral reef fish, whereas topographic complexity, benthic habitat structure, and benthic cover had little association with reef fish distribution in the Mariana Archipelago.

Kitiona et al. (2016) completed a study of the impacts climate and ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.7.4). The evaluation of environmental variables showed that certain climate parameters (e.g., SST anomaly, sea level height, precipitation, and tropical storm days) are likely linked to fishery performance. It has also noted that larger natural disturbances in recent decades, such as cyclones and tsunamis, negatively impacted reef fish assemblages and lowered CPUE of reef fish in American Samoa (Ochavillo et al. 2012).

Little information exists on the larval and juvenile life stages of bottomfish in the MHI, though the larvae and juveniles are typically found in very different habitats than their adult counterparts (Moffitt 2006). Larvae in the MHI exhibit a high degree of self-recruitment and connectivity, and the presence of zonal currents may play a part in influencing larval transport and connectivity (Wren et al. 2016). In addition, mesoscale eddies are thought to play a major role in retention of larvae and recruitment for fish stocks around the MHI, and parrotfish in the MHI likely utilize eddies to retain larvae near their settling grounds (Lobel and Robinson 1986; Lobel 1989; Shulzitski et al. 2017; Wren and Kobayashi 2016). A more recent project evaluating larval fish assemblages in association with water masses and mesoscale dynamics that govern them suggested that larval assemblages depend on species-based interactions between their spawning strategies and these processes (León-Chávez et al. 2010). Similarly, a study on the impact of mesoscale eddies on the migration of Japanese eel larvae found that there was a negative relationship between the eel recruitment index and the eddy index subtropical countercurrent, indicating that eddies play some sort of role in migration of the species (Chang et al. 2017).

Uku and its Fishery in the Main Hawaiian Islands

The green jobfish (*Aprion virescens*), known as uku in Hawaii, is a non-Deep-7 bottomfish that inhabits deep lagoons, channels, and inshore reefs from the surface down to about 100 - 135 m (Asher et al. 2017; Haight et al. 1993b). It is among the most common roving predatory marine species in the MHI (Asher et al. 2017). The most recent stock assessment of uku in the MHI was done by Nadon (2017), where it was suggested that population abundance appeared to be increasing from 2003 to 2016.

Uku reach sexual maturity during the spring and summer before spawning until fall or early winter; they begin spawning in May before their peak in June (Everson et al. 1989). The green jobfish are generally known to aggregate in shallower waters, such as those above Penguin Banks, during summer months for spawning purposes and are caught during daylight hours (Haight et al. 1993a; Haight et al. 1993b). The timing of their spawning aggregations may also be associated with increases in SST and/or day length to ensure ideal conditions for their larvae (Walsh 1987). It has been found that areas active with spawning during the summer had prolonged absences of the species from October to April due to seasonal migrations (Meyer et al. 2007). Unsurprisingly, around the MHI, the majority of uku are typically caught over Penguin Banks during the summer, as are typically targeted when they aggregate for spawning (Everson et al. 1989; Parke 2007).

Uku size at 50 percent sexual maturity for females is 425 to 475 mm fork length (FL), and the smallest uku with vitellogenic (stage II) ovaries during spawning was just 429 mm (Everson et al. 1989; Haight et al. 1993). The slope of the logistic curve fit to size at sexual maturity data for uku was relatively steep, suggesting that uku grow rapidly and quickly recruit into the fishery

(Everson et al. 1989). Uku congregate around the MHI in expected 1:1 sex ratio, and likely release multiple egg batches over the course of a spawning season (Everson et al. 1989).

Uku are harvested by a wide range of gear types, including deep- and shallow-set (i.e., inshore) handlining, cast netting, and trolling. Deep-set handline was primarily focused on for this data integration assessment due to the amount of consistent data available and its apparent dominance in the MHI uku fishery. There was generally more structural variability apparent in handline trips, as the fishermen should catch uku with handline if that is what they are targeting due to the gear's high selectivity. Of all gear types that are used to harvest uku, the deep-set handline consistently had the highest CPUE of the four gears considered by nearly an order of magnitude; however, while CPUE for deep-set handline trended downwards over the course of the time series, the CPUE for inshore handline, cast netting, and trolling with lures slightly increased over the same period (Figure 33). Trolling (with lure) to harvest uku had the second-highest CPUE for several years of the CPUE time series, but this gear type was not taken further in the assessment because there is no good understanding of trolling effort for uku; troll fishers are usually targeting pelagic species and are not reporting "zero" catch on trips where there is no uku catch.

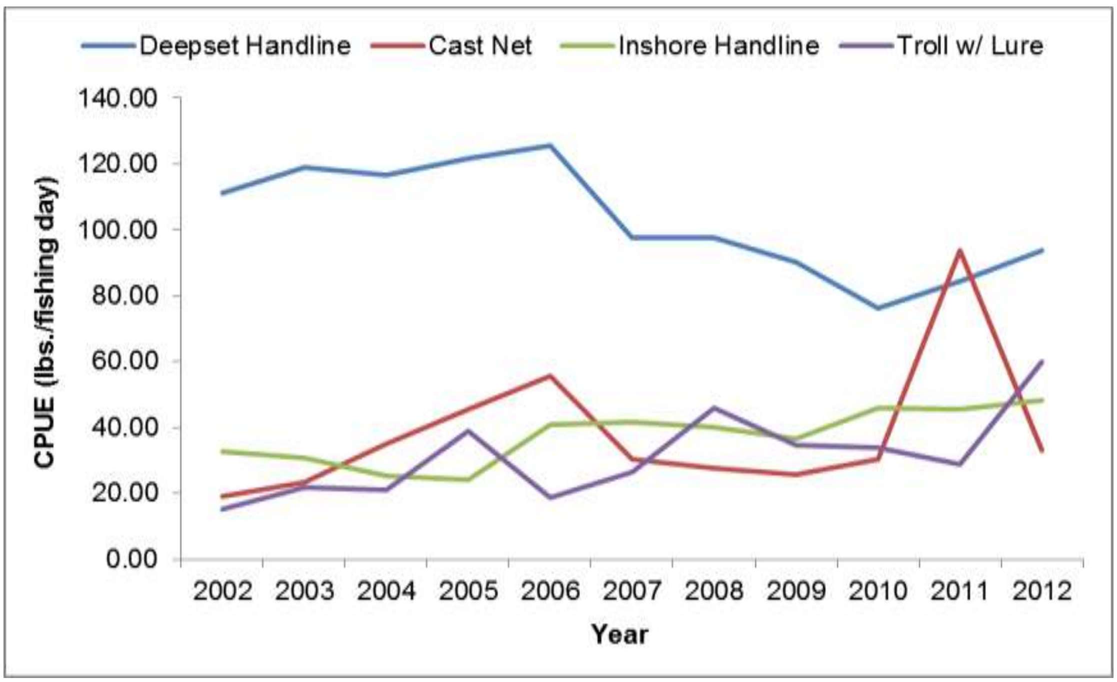

Figure 33. CPUE for uku harvested in the MHI for four top gear types from 2002-2012

The annual average weight per fish from 2002 to 2012 was 8.59 pounds, ranging from 8.25 pounds in 2008 to 8.94 pounds in 2014 (Figure 34). These results agree well with the annual average weight-per-fish determined by Moffitt et al. (2005). Using a weight-to-length conversion for uku (Sundberg and Underkoffler 2011) it was determined that the average length per fish was roughly 63 to 65 cm Total Length (TL). From there, a length-to-age curve was utilized (O'Malley et al. 2016) to estimate the approximate age that uku individuals recruit into the fishery around the MHI to be about two years. It is reasonable to infer that the CPUE data analyzed here is comprised mostly of fish that recruited into the fishery at two years of age.

Though Sundberg and Underkoffler (2011) suggested that an uku of eight to nine pounds is likely 63 to 65 cm TL, Everson et al. (1989) noted that uku of such size in the main Hawaiian

Islands were 95 percent mature, indicating that the uku may have recruited to the fishery earlier as well. For uku, it was determined that 100 percent maturity was reached by the 50 cm size classes, but it is important to note that disparities in size and at sexual maturity between areas may reflect differences in resource utilization and growth allocation (Everson et al. 1989). Uku have been found to be homogenously dispersed across all available depth and habitat strata with significant regional differences no matter the depth strata or inclusion of habitat (Asher et al. 2017).

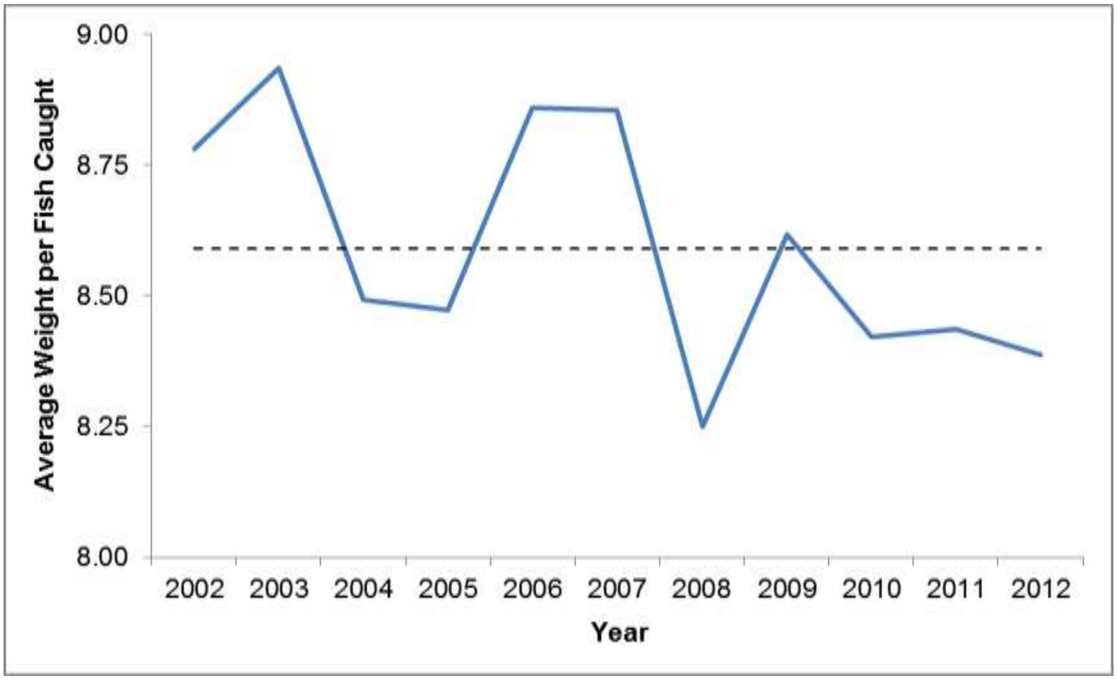

Figure 34. Average annual weight per fish (lb) for uku (*Aprion virescens*) harvested around the Main Hawaiian Islands from 2002-2012

3.2 MULTIVARIATE ENSO INDEX

The El Niño Southern Oscillation (ENSO) is Earth's strongest interannual climate fluctuation and is the most important and representative phenomenon in the ocean-atmosphere system on these time scales (Mazzarella et al. 2013; Wolter and Timlin 2011). To measure the response of the uku fishery to interannual environmental shifts, such as those due to ENSO, data were drawn from a relatively recent index that utilizes an ensemble approach and has become the leading ENSO index called the Multivariate ENSO Index Version 2 (MEI.v2). The MEI utilizes of five different environmental parameters across the tropical Pacific Ocean to derive its value: SST, sea level pressure (SLP), surface zonal winds, surface meridional winds, and outgoing longwave radiation (OLR; NOAA 2019). Notable environmental features during the typical peak of ENSO during late Fall/early Winter are anomalously warm SST across the east-central equatorial Pacific, anomalously low SLP over the eastern tropical Pacific, reduction of tropical Pacific easterly trade winds, and increased OLR over the Western Pacific (Figure 35; NOAA 2019). In MEI.v2, the measures of SST, SLP, and surface zonal and meridional winds are obtained from the JRA-55 global atmospheric reanalysis by the Japan Meteorological Agency (see Kobayashi et al. 2015), while the measures of OLR were gathered from the NOAA Climate Data Record of Monthly OLR (Lee 2018). While there are positive MEI values every few years, the last several major ENSO events occurred in 1983, 1998, and 2016 (Figure 36; NOAA 2019).

The CPUE (catch in pounds per fishing trip/day) and environmental data were standardized by both average and standard deviation so the time series would be comparable, and all covariates would have equitability. Phase lag was incorporated from one to six years. The correlation coefficient for the comparison between standardized uku CPUE from the MHI and the standardized MEI.v2 was -0.729 (Figure 37) and the coefficient of determination (R^2) was 0.53 (Figure 38), indicating a strong inverse relationship between the variables. The covariates suggest that as the MEI.v2 increases, uku CPUE in the MHI decreases, and vice versa.

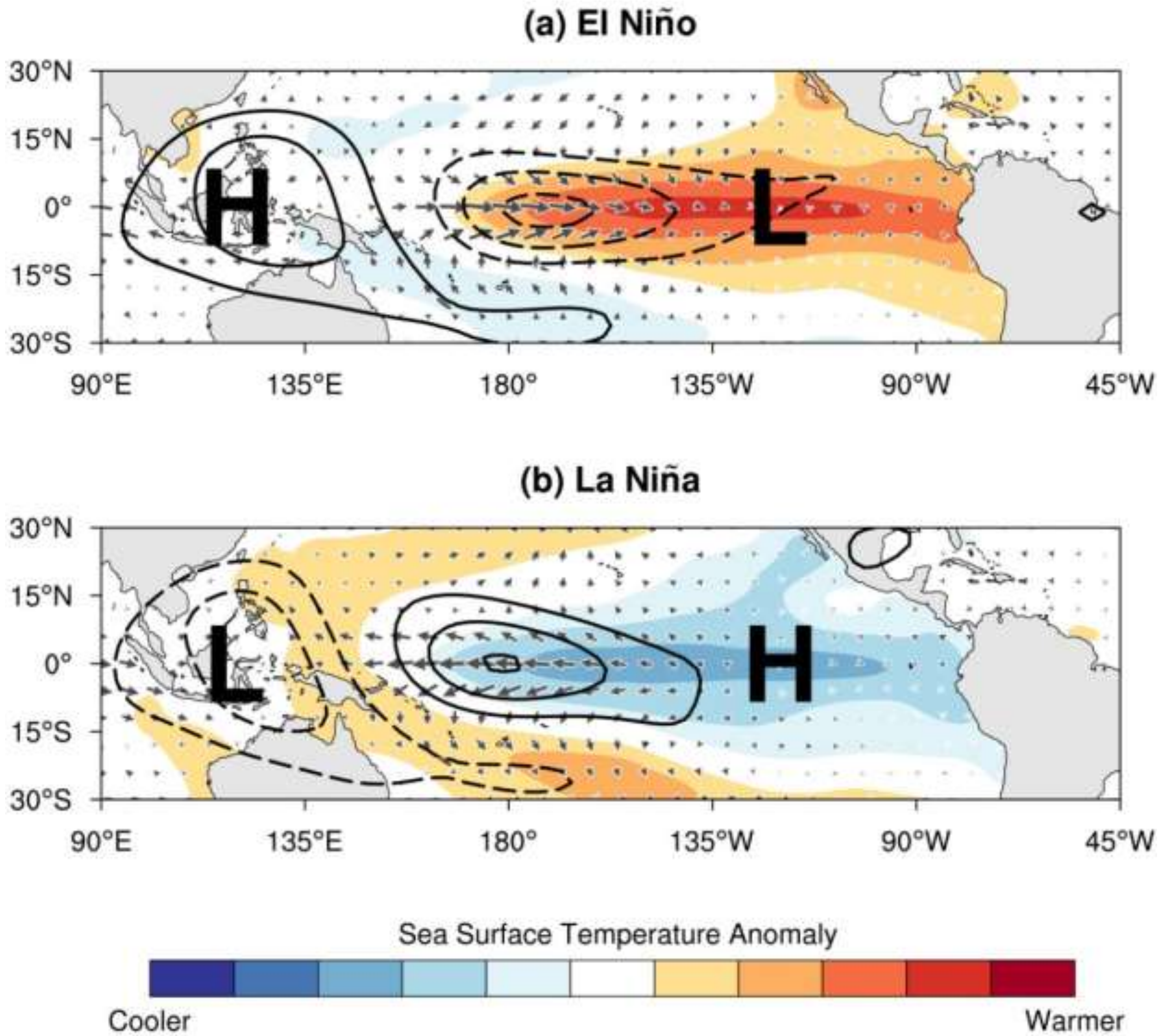

Figure 35. Diagram showing the physical mechanisms by which the SST (shaded), OLR (contours), surface zonal and meridional winds (vectors), and sea level pressure (represented by "H" and "L") determine the wintertime Multivariate ENSO Index (MEI) during (a) El Niño and (b) La Niña events" (from NOAA 2019)

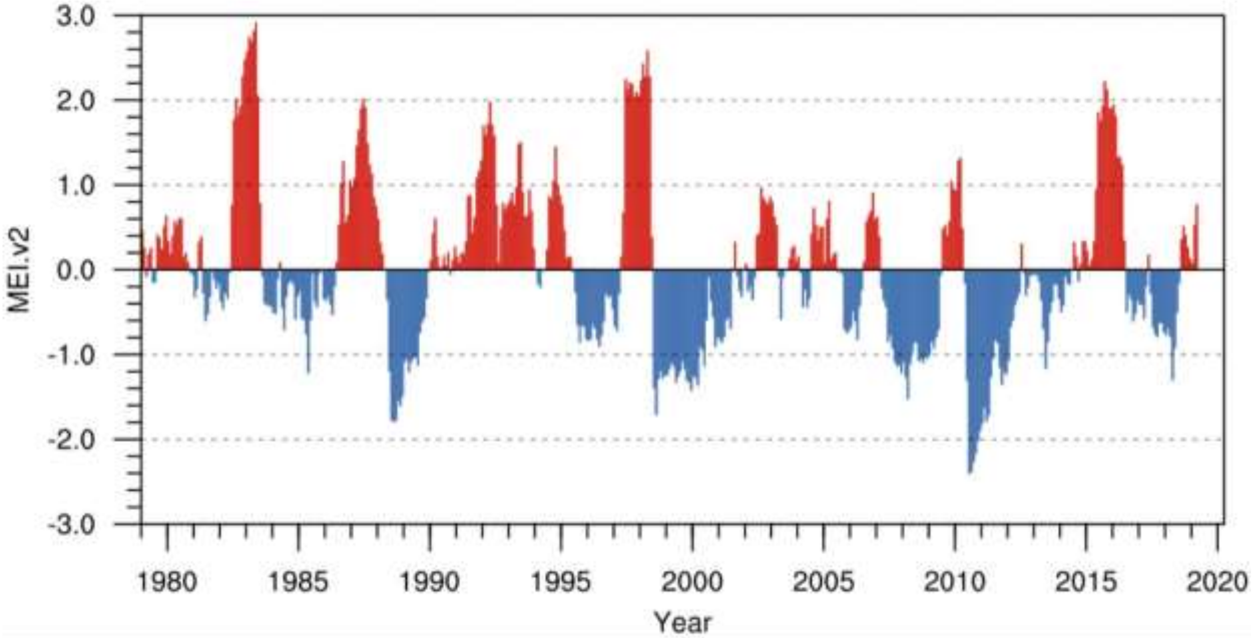

Figure 36. Time series of the Multivariate ENSO Index (MEI) v2 from 1980-2019

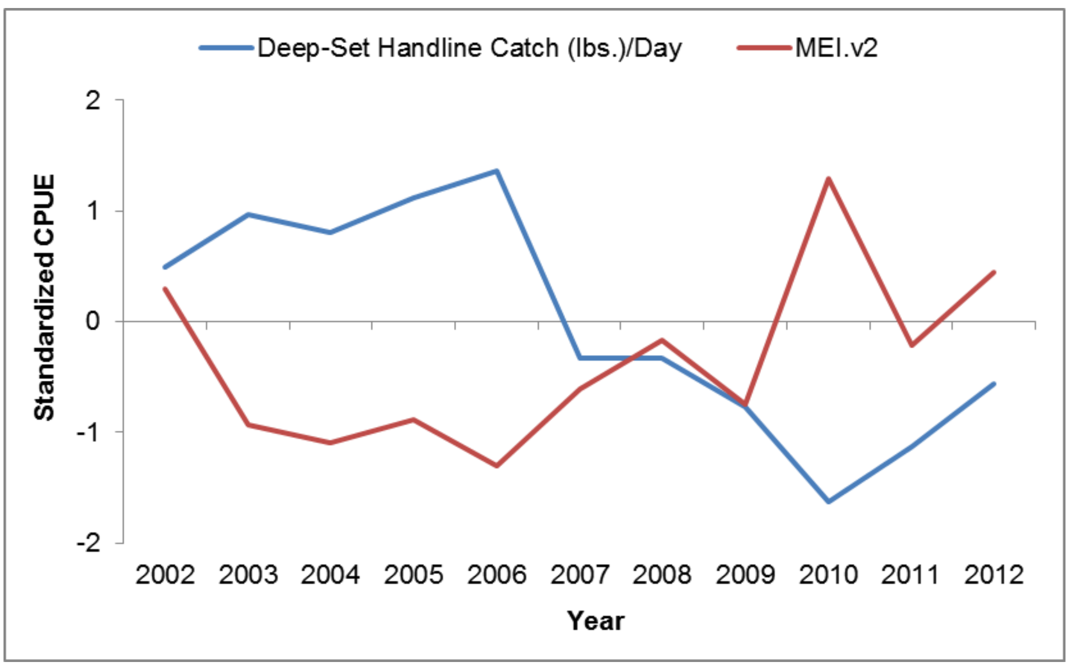

Figure 37. Comparison of standardized MHI Deep-Set Handline CPUE and MEI.v2 with a phase lag of two years from 2002-2012 (*r* = -0.729)

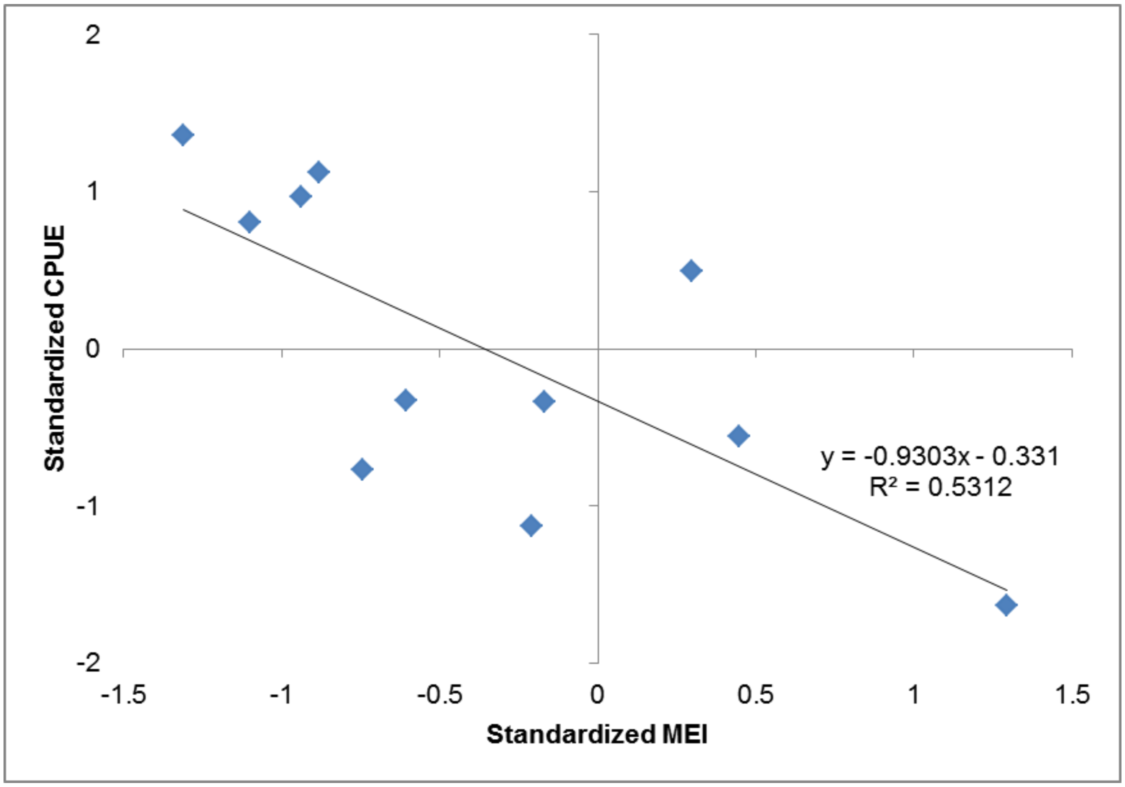

Figure 38. Standardized CPUE for uku from the MHI from 2002-2012 plotted against standardized MEI.v2 with a phase lag of two years

3.3 SURFACE ZONAL CURRENTS

The surface circulation in the tropical Pacific Ocean is complex and undergoes a large amount of short- and long-term variability due to both shifts in major winds as well as thermohaline structure of surrounding water masses (Wyriki 1965). It has been suggested in the past that the current flow near the MHI is responsible for the variability in larval assemblages and distribution in the area (Miller 1974). Given the vital role zonal flow plays in vorticity, it was inferred that the parameter itself may possess some sort of fishery ecosystem relationship with uku, whose spawning assemblages are known to congregate in shallow waters above Penguin Banks during the summer months (Haight et al. 1993a; Haight et al. 1993b). A summary of surface zonal currents and vorticity in the waters surrounding the MHI from 2004 is depicted in Figure 39. One of the major surface currents in this region, the North Equatorial Current, was also analyzed for the purposes of this study, with moderate relationships between NEC flow with a phase lag of two years and uku CPUE (r = 0.304).

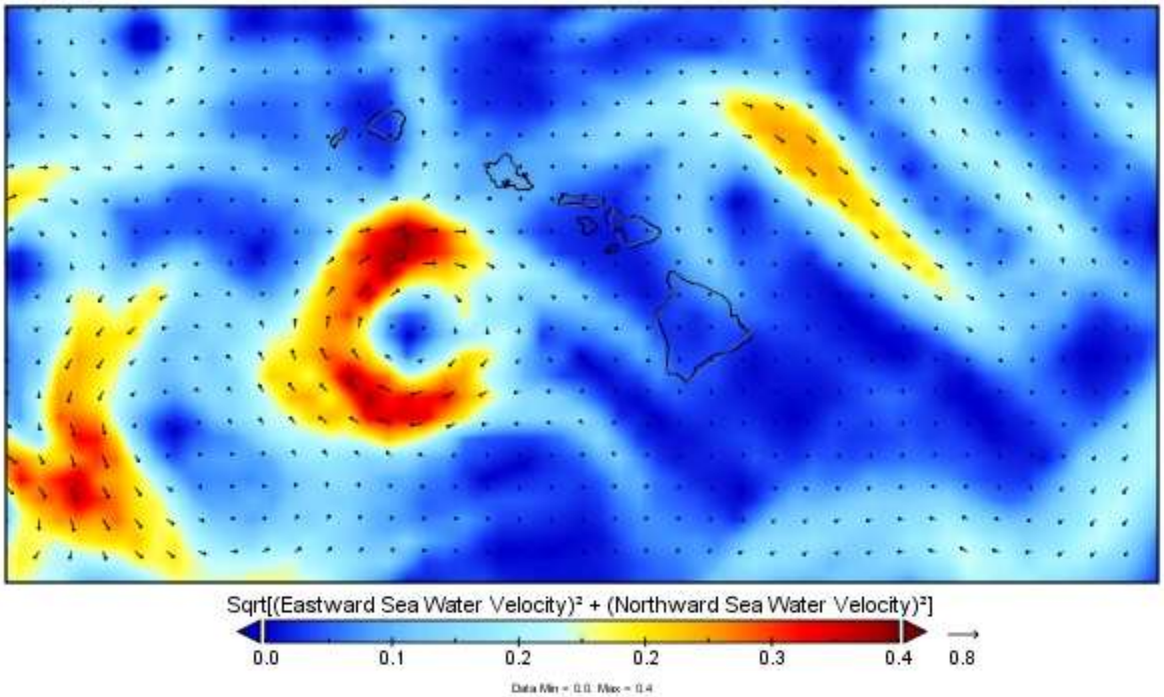

Figure 39. Example of eastward sea water current velocity around the MHI (from 2004)

Similar to comparisons with the MEI.v2, both CPUE (catch in pounds per fishing trip/day) and environmental data were standardized by both average and standard deviation so the time series would be comparable, and all covariates would have equitability. Phase lag was incorporated from one to six years. The correlation coefficient for the comparison between standardized uku CPUE from the MHI and the standardized average summertime zonal current flow in the same area was 0.748 (Figure 40) and the coefficient of determination (R^2) was approximately 0.56 (Figure 41), indicating a strong relationship between the variables. The covariates suggest that as the average summertime zonal current increases, uku CPUE in the MHI also increases.

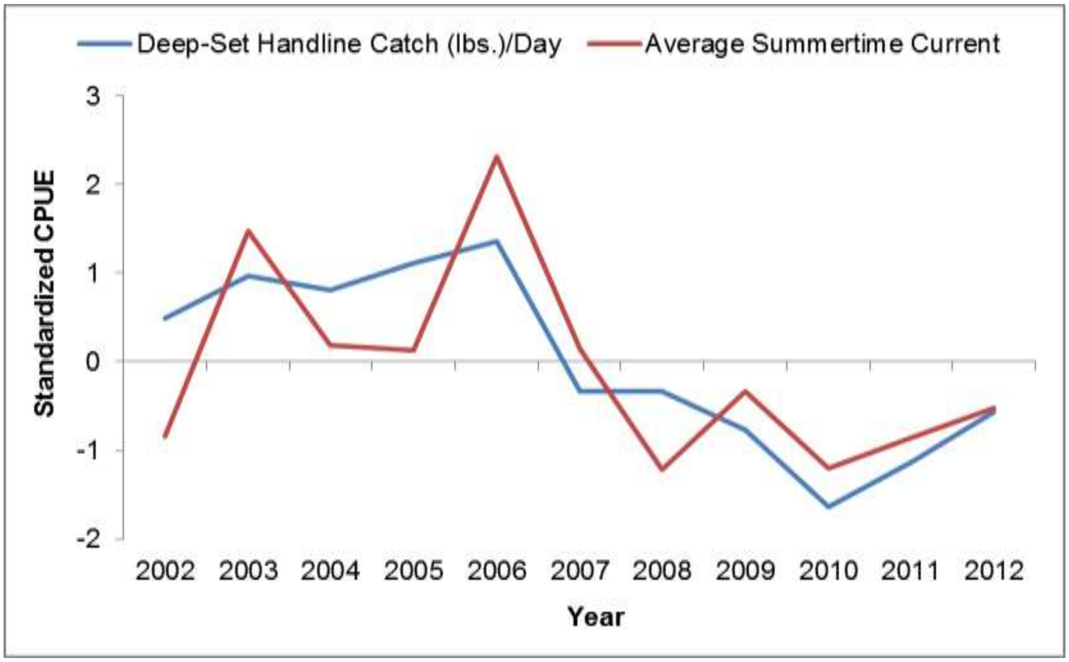

Figure 40. Comparison of standardized MHI Deep-Set Handline CPUE and the average summertime zonal current with a phase lag of two years from 2002-2012 (*r* = 0.748)

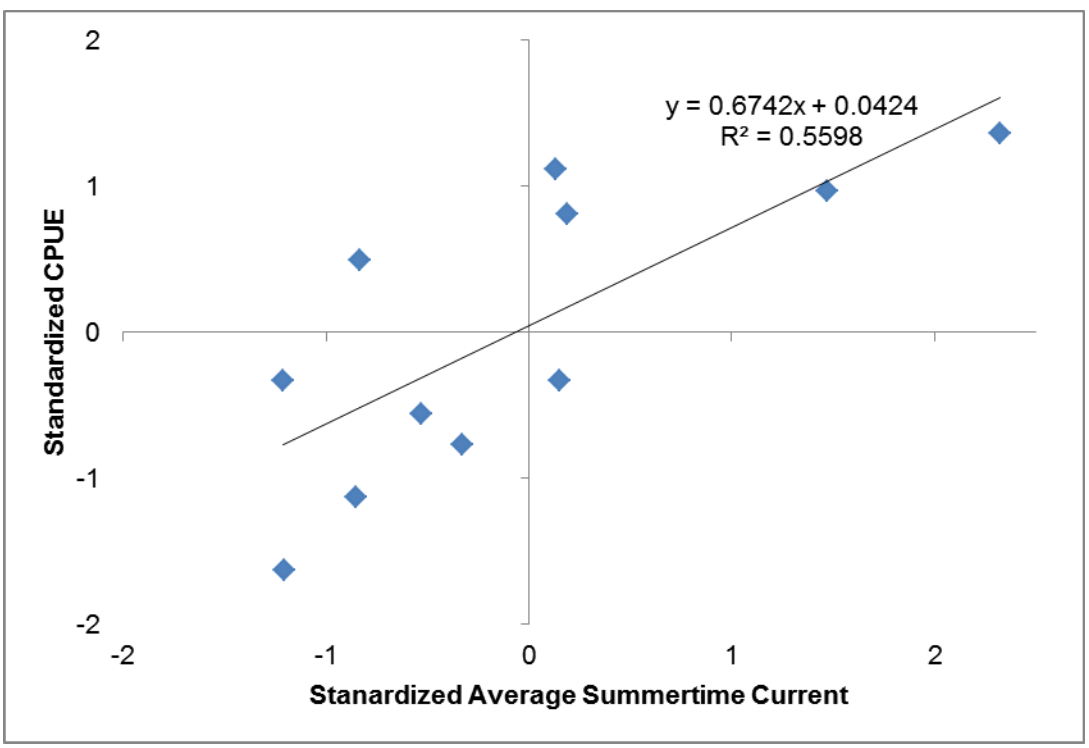

Figure 41. Standardized CPUE for uku from the MHI from 2002-2012 plotted against standardized average summertime zonal current with a phase lag of two years

3.4 RECENT RELEVANT ABSTRACTS

In this section, abstracts from primary journal articles published in 2021 and relevant to data integration are compiled. Collecting the abstracts of these articles is intended to further the goal of this chapter being used to guide adaptive management.

Becker EA, Forney KA, Oleson EM, Bradford AL, Moore JE, Barlow J. 2021. Habitat-based density estimates for cetaceans within the waters of the U.S. Exclusive Economic Zone around the Hawaiian Archipelago. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-116, 38 p. https://doi.org/10.25923/x9q9-rd73.

The Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) 2017 was conducted in waters within the United States (U.S.) Exclusive Economic Zone (EEZ) around the Hawaiian Archipelago (henceforth “Hawaiian EEZ” for brevity) from 6 July through 1 December 2017 (Yano et al. 2018). The primary objective of this line-transect survey was to collect cetacean sighting data to support the derivation of cetacean density estimates using both design-based analyses and habitat modeling techniques. This report summarizes the results of the habitat modeling effort. The design-based estimates are described separately in Bradford et al. (in review).

Berger AM, Deroba JJ, Bosley KM, Goethel DR, Langseth BJ, Schueller AM, Hanselman DH. 2021. Incoherent dimensionality in fisheries management: consequences of misaligned stock assessment and population boundaries. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsaa203.

Fisheries policy inherently relies on an explicit definition of management boundaries that delineate the spatial extent over which stocks are assessed and regulations are implemented. However, management boundaries tend to be static and determined by politically negotiated or historically identified population (or multi-species) units, which create a potential disconnect with underlying, dynamic population structure. The consequences of incoherent management and population or stock boundaries were explored through the application of a two-area spatial simulation–estimation framework. Results highlight the importance of aligning management assessment areas with underlying population structure and processes, especially when fishing mortality is disproportionate to vulnerable biomass among management areas, demographic parameters (growth and maturity) are not homogenous within management areas, and connectivity (via recruitment or movement) unknowingly exists among management areas. Bias and risk were greater for assessments that incorrectly span multiple population segments (PSs) compared to assessments that cover a subset of a PS, and these results were exacerbated when there was connectivity between PSs. Directed studies and due consideration of critical PSs, spatially explicit models, and dynamic management options that help align management and population boundaries would likely reduce estimation biases and management risk, as would closely coordinated management that functions across population boundaries.

Donovan MK, Burkepile DE, Kratochwill C, Shlesinger T, Sully S, Oliver TA, Hodgson G, Freiwald J, van Woesik R. 2021. Local conditions magnify coral loss after marine heatwaves. *Science*. *372*(6545):977-80. https://doi.org/10.1126/science.abd9464.

Climate change threatens coral reefs by causing heat stress events that lead to widespread coral bleaching and mortality. Given the global nature of these mass coral mortality events, recent studies argue that mitigating climate change is the only path to conserve coral reefs. Using a global analysis of 223 sites, we show that local stressors act synergistically with climate change to kill corals. Local factors such as high abundance of macroalgae or urchins magnified coral loss in the year after bleaching. Notably, the combined effects of increasing heat stress and macroalgae intensified coral loss. Our results offer an optimistic premise that effective local management, alongside global efforts to mitigate climate change, can help coral reefs survive the Anthropocene.

Friedland KD, Smolinski S, Tanaka KR. 2021. Contrasting patterns in the occurrence and biomass centers of gravity among fish and macroinvertebrates in a continental shelf ecosystem. *Ecol Evol*. *11*(5). https://doi.org/10.1002/ece3.7150.

The distribution of a group of fish and macroinvertebrates (n = 52) resident in the US Northeast Shelf large marine ecosystem were characterized with species distribution models (SDM), which in turn were used to estimate occurrence and biomass center of gravity (COG). The SDMs were fit using random forest machine learning and were informed with a range of physical and biological variables. The estimated probability of occurrence and biomass from the models provided the weightings to determine depth, distance to the coast, and along-shelf distance COG. The COGs of occupancy and biomass habitat tended to be separated by distances averaging 50 km, which approximates half of the minor axis of the subject ecosystem. During the study period (1978–2018), the biomass COG has tended to shift to further offshore positions whereas occupancy habitat has stayed at a regular spacing from the coastline. Both habitat types have shifted their along-shelf distances, indicating a general movement to higher latitude or to the Northeast for this ecosystem. However, biomass tended to occur at lower latitudes in the spring and higher latitude in the fall in a response to seasonal conditions. Distribution of habitat in relation to depth reveals a divergence in response with occupancy habitat shallowing over time and biomass habitat distributing in progressively deeper water. These results suggest that climate forced change in distribution will differentially affect occurrence and biomass of marine taxa, which will likely affect the organization of ecosystems and the manner in which human populations utilize marine resources.

Gonzalez-Mon B, Bodin Ö, Lindkvist E, Frawley TH, Giron-Nava A, Basurto X, Nenadovic M, Schlüter M. 2021. Spatial diversification as a mechanism to adapt to environmental changes in small-scale fisheries. Environmental Science & Policy, 116, pp.246-257.

Small-scale fisheries' actors increasingly face new challenges, including climate driven shifts in marine resource distribution and productivity. Diversification of target species and fishing locations is a key mechanism to adapt to such changes and maintain fisheries livelihoods. Here we explore environmental and institutional factors mediating how patterns of spatial diversification (i.e., utilization of alternative fishing grounds) and target species diversification change over time. Using small-scale fisheries in Baja California Sur (Mexico) as a case study, we adopt a social-ecological network approach to conduct a spatially explicit analysis of fisheries landings data (2008–2016). This approach quantifies relative patterns of diversification, and when combined with a qualitative analysis of existing literature, enables us to illuminate institutional and environmental factors that may influence diversification strategies. Our results indicate that interannual changes in spatial diversification are correlated with regional oceanographic change, while illustrating the heterogeneity and dynamism of diversification strategies. Rather than acting in isolation, we hypothesize that environmental drivers likely operate in combination with existing fisheries regulations and local socioeconomic context to mediate spatial diversification. We argue that small-scale fisheries policies need to better account such linkages as we move towards an increasingly variable environment. Overall, our results highlight spatial diversification as a dynamic process and constitute an important step towards understanding and managing the complex mechanisms through which environmental changes affect small-scale fisheries.

Heneghan RF, Galbraith E, Blanchard JL, Harrison C, Barrier N, Bulman C, Cheung W, Coll M, Eddy TD, Erauskin-Extramiana M, Everett JD, et al. 2021. Disentangling diverse responses to climate change among global marine ecosystem models. Progress in Oceanography:102659 https://doi.org/10.1016/j.pocean.2021.102659.

Climate change is warming the ocean and impacting lower trophic level (LTL) organisms. Marine ecosystem models can provide estimates of how these changes will propagate to larger animals and impact societal services such as fisheries, but at present these estimates vary widely. A better understanding of what drives this inter-model variation will improve our ability to project fisheries and other ecosystem services into the future, while also helping to identify uncertainties in process understanding. Here, we explore the mechanisms that underlie the diversity of responses to changes in temperature and LTLs in eight global marine ecosystem models from the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP). Temperature and LTL impacts on total consumer biomass and ecosystem structure (defined as the relative change of small and large organism biomass) were isolated using a comparative experimental protocol. Total model biomass varied between −35% to +3% in response to warming, and -17% to +15% in response to LTL changes. There was little consensus about the spatial redistribution of biomass or changes in the balance between small and large organisms (ecosystem structure) in response to warming, an LTL impacts on total consumer biomass varied depending on the choice of LTL forcing terms. Overall, climate change impacts on consumer biomass and ecosystem structure are well approximated by the sum of temperature and LTL impacts, indicating an absence of nonlinear interaction between the models' drivers. Our results highlight a lack of theoretical clarity about how to represent fundamental ecological mechanisms, most importantly how temperature impacts scale from individual to ecosystem level, and the need to better understand the two-way coupling between LTL organisms and consumers. We finish by identifying future research needs to strengthen global marine ecosystem modelling and improve projections of climate change impacts.

Hyrenbach KD, Ishizaki A, Polovina J, Ellgen S (Eds.). 2021. The factors influencing albatross interactions in the Hawaii longline fishery: Towards identifying drivers and quantifying impacts. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-122, 163 p. https://doi.org/10.25923/nb95-gs31.

The Hawaii longline fishery has been required to use seabird mitigation measures under the Pacific Pelagic Fishery Management Plan (current Fishery Ecosystem Plan, or FEP) since 2001. In the past decade since the successful implementation of seabird mitigation measures, the fishery has seen a gradual increasing trend in Black-footed (*Phoebastria nigripes*, BFAL) and Laysan (*P. immutabilis*, LAAL) albatross interactions, with higher rates of Black-footed albatross interactions since 2015. A published analysis conducted by Gilman and colleagues (2016) using data from October 2004 to May 2014, indicated that albatross interaction rates significantly increased during years of higher annual mean multivariate El Niño index (MEI), suggesting that oceanographic changes may have contributed to these changes in albatross catch rates. This analysis also showed a significant increasing trend in the number of albatross attending fishing vessels which may have contributed to the increasing catch rates. Moreover, the higher interaction rates observed during the recent El Niño event (2015–2016) further underscore the potential links between ocean conditions and albatross longline interactions.

Jardim E, Azevedo M, Brodziak J, Brooks EN, Johnson KF, Klibansky N, Millar CP, Minto C, Mosqueira I, Nash RD, et al. 2021. Operationalizing ensemble models for scientific advice to fisheries management. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsab010.

This paper explores the possibility of using the ensemble modelling paradigm to fully capture assessment uncertainty and improve the robustness of advice provision. We identify and discuss advantages and challenges of ensemble modelling approaches in the context of scientific advice. There are uncertainties associated with every phase in the stock assessment process: data collection, assessment model choice, model assumptions, interpretation of risk, up to the implementation of management advice. Additionally, the dynamics of fish populations are complex, and our incomplete understanding of those dynamics and limited observations of important mechanisms, necessitate that models are simpler than nature. The aim is for the model to capture enough of the dynamics to accurately estimate trends and abundance, and provide the basis for robust advice about sustainable harvests. The status quo approach to assessment modelling has been to identify the “best” model and generate advice from that model, mostly ignoring advice from other model configurations regardless of how closely they performed relative to the chosen model. We discuss and make suggestions about the utility of ensemble models, including revisions to the formal process of providing advice to management bodies, and recommend further research to evaluate potential gains in modelling and advice performance.

Kaplan IC, Gaichas SK, Stawitz CC, Lynch PD, Marshall KN, Deroba JJ, Masi M, Brodziak JK, Aydin KY, Holsman K, et al. 2021. Management Strategy Evaluation: Allowing the Light on the Hill to Illuminate More Than One Species. Frontiers in Marine Science. 8:688. https://doi.org/10.3389/fmars.2021.624355.

Management strategy evaluation (MSE) is a simulation approach that serves as a “light on the hill” (Smith, 1994) to test options for marine management, monitoring, and assessment against simulated ecosystem and fishery dynamics, including uncertainty in ecological and fishery processes and observations. MSE has become a key method to evaluate trade-offs between management objectives and to communicate with decision makers. Here we describe how and why MSE is continuing to grow from a single species approach to one relevant to multi-species and ecosystem-based management. In particular, different ecosystem modeling approaches can fit within the MSE process to meet particular natural resource management needs. We present four case studies that illustrate how MSE is expanding to include ecosystem considerations and ecosystem models as ‘operating models’ (i.e., virtual test worlds), to simulate monitoring, assessment, and harvest control rules, and to evaluate tradeoffs via performance metrics. We highlight United States case studies related to fisheries regulations and climate, which support NOAA’s policy goals related to the Ecosystem Based Fishery Roadmap and Climate Science Strategy but vary in the complexity of population, ecosystem, and assessment representation. We emphasize methods, tool development, and lessons learned that are relevant beyond the United States, and the additional benefits relative to single-species MSE approaches.

Kasperski S, DePiper GS, Blake S, Colburn LL, Jepson M, Haynie1 AC, Karnauskas M, Leong KM, Lipton D, Masi M, et al. 2021. Assessing the State of Coupled Social-Ecological

Modeling in Support of Ecosystem Based Fisheries Management in the U.S. Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.631400.

There has been a proliferation of coupled social-ecological systems (SES) models created and published in recent years. However, the degree of coupling between natural and social systems varies widely across the different coupled models and is often a function of the disciplinary background of the team conducting the research. This manuscript examines models developed for and used by NOAA Fisheries in support of Ecosystem Based Fisheries Management (EBFM) in the United States. It provides resource managers and interdisciplinary scientists insights on the strengths and weaknesses of the most commonly used SES models: end-to-end models, conceptual models, bioeconomic models, management strategy evaluations (MSEs), fisher behavior models, integrated social vulnerability models, and regional economic impact models. These model types are not unique to the literature, but allow us to differentiate between one-way coupled models – where outputs from one model are inputs into a second model of another discipline with no feedback to the first model, and two-way coupled models – where there are linkages between the natural and social system models. For a model to provide useful strategic or tactical advice, it should only be coupled to the degree necessary to understand the important dynamics/responses of the system and to create management-relevant performance metrics or potential risks from an (in)action. However, one key finding is to not wait to integrate! This paper highlights the importance of "when" the coupling happens, as timing affects the ability to fully address management questions and multi-sectoral usage conflicts that consider the full SES for EBFM or ecosystem based management (EBM) more generally.

McNamara KE, Westoby R, Chandra A. 2021. Exploring climate-driven non-economic loss and damage in the Pacific Islands. Current Opinion in Environmental Sustainability, 50, pp.1-11.

Non-economic loss and damage induced by climate change in the Pacific Islands region has been reported as fears of cultural loss, deterioration of vital ecosystem services, and dislocation from ancestral lands, among others. This paper undertakes an in-depth systematic review of literature from the frontlines of the Pacific Islands to ascertain the complexities of non-economic loss and damage from climate change. We synthesise knowledge to date on different but inter-connected categories of non-economic loss and damage, namely: human mobility and territory, cultural heritage and Indigenous knowledge, life and health, biodiversity and ecosystem services, and sense of place and social cohesion. Identifying gaps and possibilities for future research agendas is presented. Synthesising knowledge to date and identifying remaining gaps about non-economic loss and damage is an important step in taking stock of what we already know and fostering action and support for addressing loss and damage in the years to come.

Politikos DV, Rose KA, Curchitser EN, Checkley DM Jr , Rykaczewski RR, Fiechter J. 2021. Climate variation and anchovy recruitment in the California current: a cause-and-effect analysis of an end-to-end model simulation. Marine Ecology Progress Series.Volume 680:111-136. https://doi.org/10.3354/meps13853.

Interannual and regime (decadal) scale changes in climate affect the spatial distribution and productivity of marine fish species in numerous ecosystems. We analyzed a historical simulation (1965-2000) from an end-to-end ecosystem model of anchovy population dynamics for the California Current System to untangle the effects of warm versus cool conditions on recruitment. A 3-dimensional coupled hydrodynamic-NPZD (nitrogen-phytoplankton-zooplankton-detritus) model (ROMS-NEMURO) provided the physical conditions (circulation, temperature) and 3 zooplankton concentrations as inputs to an anchovy full life cycle individual-based model (IBM). Our analysis was focused on isolating the effects of the well-documented El Niño Southern Oscillation signal and 3 climate regimes on spawning habitat, development, and survival of eggs and yolk-sac larvae, growth and survival of larvae and juveniles, and ultimately recruitment of anchovy. The major drivers of lowered recruitment success in warm years and in warmer regimes were reduced survival and growth rates of eggs and larvae that resulted from the poleward shift of adults in response to warmer temperatures prior to spawning. Three model-data comparisons showed the model deviated from empirically derived values of annual recruitment success but agreed with data for annual mean latitude of egg distributions and predicted larval consumption rates versus measured zooplankton concentrations. More effort is needed to improve certain biological aspects of the IBM so that it can replicate empirically estimated recruitment fluctuations. Overall, the altered responses of anchovy to changing climate in the California Current domain illustrate the benefit of the present mechanistic approach to infer how anchovy may respond under future ecosystem conditions.

Smith JA, Tommasi D, Welch H, Hazen EL, Sweeney J, Brodie S, Muhling B, Stohs SM, Jacox MG. 2021. Comparing Dynamic and Static Time-Area Closures for Bycatch Mitigation: A Management Strategy Evaluation of a Swordfish Fishery. Frontiers in Marine Science. 8:272. https://doi.org/10.3389/fmars.2021.630607.

Time-area closures are a valuable tool for mitigating fisheries bycatch. There is increasing recognition that dynamic closures, which have boundaries that vary across space and time, can be more effective than static closures at protecting mobile species in dynamic environments. We created a management strategy evaluation to compare static and dynamic closures in a simulated fishery based on the California drift gillnet swordfish fishery, with closures aimed at reducing bycatch of leatherback turtles. We tested eight operating models that varied swordfish and leatherback distributions, and within each evaluated the performance of three static and five dynamic closure strategies. We repeated this under 20 and 50% simulated observer coverage to alter the data available for closure creation. We found that static closures can be effective for reducing bycatch of species with more geographically associated distributions, but to avoid redistributing bycatch the static areas closed should be based on potential (not just observed) bycatch. Only dynamic closures were effective at reducing bycatch for more dynamic leatherback distributions, and they generally reduced bycatch risk more than they reduced target catch. Dynamic closures were less likely to redistribute fishing into rarely fished areas, by leaving open pockets of lower risk habitat, but these closures were often fragmented which would create practical challenges for fishers and managers and require a mobile fleet. Given our simulation's catch rates, 20% observer coverage was sufficient to create useful closures and increasing coverage to 50% added only minor improvement in closure performance. Even strict static or dynamic closures reduced leatherback bycatch by only 30–50% per season, because the simulated leatherback distributions were broad and open areas contained considerable bycatch risk. Perfect knowledge of the leatherback distribution provided an additional 5–15% bycatch reduction over a dynamic closure with realistic predictive accuracy. This moderate level of bycatch reduction highlights the limitations of redistributing fishing effort to reduce bycatch of broadly distributed and rarely encountered species, and indicates that, for these species, spatial management may work best when used with other bycatch mitigation approaches. We recommend future research explores methods for considering model uncertainty in the spatial and temporal resolution of dynamic closures.

Syddall V, Thrush S, Fisher K, 2021. Transdisciplinary analysis of Pacific tuna fisheries: A research framework for understanding and governing oceans as social-ecological systems. *Marine Policy*, *134*, p.104783.

Western and Central Pacific (WCP) tuna fisheries are faced with complex and interlinked social and ecological challenges including high seas management issues, setting sustainable limits, human rights violations, and illegal, unreported, and unregulated (IUU) activities. However, strong but narrow disciplinary science persist to dominate governance. Effective governance across complex multi-scale systems in the WCP tuna fishery requires a more integrated understanding of social-ecological systems (SES). Transdisciplinary problem solving informed by participatory, social-ecological resilience research, and political ecology has the potential to reveal complicated interactions and connections across ocean SES networks. Social-Ecological-Oceans Systems Framework (SECO) was developed to capture the breadth and depth of the system and address interactions and connections between separate system components. SECO develops a practical integrated approach using accessible methods for addressing a large complex ocean system such as the WCP tuna fisheries. The framework offers a rapid transdisciplinary assessment and opens space for their deeper transdisciplinary analyses. This exploratory framework, as the WCP tuna case example shows, starts to reveal issues at scales that are not likely to be addressed by the strong single disciplinary approaches to governance now prevailing. The transdisciplinary research approach was developed to be responsive to diverse participants' knowledge, including local communities, scientists (social and biophysical), industry experts, economists, and fisheries managers. SECO was applied to place-specific studies, Suva, Fiji and Honiara and Gizo, Solomon Islands in the WCP tuna fishery. This validated SECO to ensure robustness and reliability

Tanaka KR, Van Houtan KS, Mailander E, Dias BS, Galginaitis C, O'Sullivan J, Lowe CG, Jorgensen SJ. 2021. North Pacific warming shifts the juvenile range of a marine apex predator. Scientific Reports. 11:3373. https://doi.org/10.1038/s41598-021-82424-9.

During the 2014–2016 North Pacific marine heatwave, unprecedented sightings of juvenile white sharks (*Carcharodon carcharias*) emerged in central California. These records contradicted the species established life history, where juveniles remain in warmer waters in the southern California Current. This spatial shift is significant as it creates potential conflicts with commercial fisheries, protected species conservation, and public safety concerns. Here, we integrate community science, photogrammetry, biologging, and mesoscale climate data to describe and explain this phenomenon. We find a dramatic increase in white sharks from 2014 to 2019 in Monterey Bay that was overwhelmingly comprised of juvenile sharks < 2.5 m in total body length. Next, we derived thermal preferences from 22 million tag measurements of 14 juvenile sharks and use this to map the cold limit of their range. Consistent with historical records, the position of this cold edge averaged 34° N from 1982 to 2013 but jumped to 38.5° during the 2014–2016 marine heat wave. In addition to a poleward shift, thermally suitable habitat for juvenile sharks declined 223.2 km2 year−1 from 1982 to 2019 and was lowest in 2015 at the peak of the heatwave. In addition to advancing the adaptive management of this apex marine predator, we discuss this opportunity to engage public on climate change through marine megafauna.

Timmers MA, Jury CP, Vicente J, Bahr KD, Webb MK, Toonen RJ. 2021. Biodiversity of coral reef cryptobiota shuffles but does not decline under the combined stressors of ocean

warming and acidification. Proceedings of the National Academy of Sciences. Volume 118: Issue 39. https://doi.org/10.1073/pnas.2103275118.

Although climate change is expected to decimate coral reefs, the combined impacts of ocean-warming and acidification on coral reef biodiversity remains largely unmeasured. Here, we present a two-year mesocosm experiment to simulate future ocean acidification and ocean-warming to quantify the impacts on species richness, community composition, and community structure. We find that species richness is equivalent between the dual-stressor and present-day treatments but that the community shuffles, undoubtedly altering ecosystem function. However, our ability to predict the outcomes of such community shuffling remains limited due to the critical knowledge gap regarding ecological functions, life histories, and distributions for most members of the cryptobenthic community that account for the majority of the biodiversity within these iconic ecosystems.

Whitney JL, Gove JM, McManus MA, Smith KA, Lecky J, Neubauer P, Phipps JE, Contreras EA, Kobayashi DR, Asner GP. 2021. Surface slicks are pelagic nurseries for diverse ocean fauna. Scientific Reports. 11(1):1-8. https://doi.org/10.1038/s41598-021-81407-0.

Most marine animals have a pelagic larval phase that develops in the coastal or open ocean. The fate of larvae has profound effects on replenishment of marine populations that are critical for human and ecosystem health. Larval ecology is expected to be tightly coupled to oceanic features, but for most taxa we know little about the interactions between larvae and the pelagic environment. Here, we provide evidence that surface slicks, a common coastal convergence feature, provide nursery habitat for diverse marine larvae, including > 100 species of commercially and ecologically important fishes. The vast majority of invertebrate and larval fish taxa sampled had mean densities 2–110 times higher in slicks than in ambient water. Combining in-situ surveys with remote sensing, we estimate that slicks contain 39% of neustonic larval fishes, 26% of surface-dwelling zooplankton (prey), and 75% of floating organic debris (shelter) in our 1000 km^2 study area in Hawai‘i. Results indicate late-larval fishes actively select slick habitats to capitalize on concentrations of diverse prey and shelter. By providing these survival advantages, surface slicks enhance larval supply and replenishment of adult populations from coral reef, epipelagic, and deep-water ecosystems. Our findings suggest that slicks play a critically important role in enhancing productivity in tropical marine ecosystems.

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APPENDIX A: LIST OF SPECIES

HAWAII MANAGEMENT UNIT SPECIES

1. MHI Deep-7 Bottomfish Multi-Species Stock Complex (FSSI)

DAR Species Code	Species Name	Scientific Name
19	pink snapper (‘ōpakapaka)	*Pristipomoides filamentosus*
22	longtail snapper (onaga)	*Etelis coruscans*
21	squirrelfish snapper (ehu)	*Etelis carbunculus*
15	sea bass (hapu‘upu‘u)	*Epinephelus quernus*
97	snapper (gindai)	*Pristipomoides zonatus*
17	pink snapper (kalekale)	*Pristipomoides sieboldii*
58	silver jaw jobfish (lehi)	*Aphareus rutilans*

2. MHI Non-Deep-7 Bottomfish Multi-Species Stock Complex (non-FSSI)

DAR Species Code	Species Name	Scientific Name
20	gray jobfish (uku)	*Aprion virescens*

3. Seamount groundfish Complex (non-FSSI)

DAR Species Code	Species Name	Scientific Name
140	Armorhead	*Pentaceros wheeleri*
141	Alfonsin	*Beryx splendens*
None	Ratfish/butterfish	*Hyperoglyphe japonica*

4. Crustacean deep-water shrimp Complex (non-FSSI)

DAR Species Code	Species Name	Scientific Name
708	deepwater shrimp	*Heterocarpus* spp.

709	deepwater shrimp (ensifer)	*Heterocarpus* spp.

5. Crustacean Kona crab Complex (non-FSSI)

DAR Species Code	Species Name	Scientific Name
701	Kona crab	*Ranina ranina*

6. ‘Au‘au Channel Black Coral Complex (non-FSSI)

DAR Species Code	Species Name	Scientific Name
860	Black Coral	*Antipathes griggi*
860	Black Coral	*Antipathes grandis*
860	Black Coral	*Myriopathes ulex*

7. Precious corals on identified and exploratory beds (non-FSSI)

DAR Species Code	Species Name	Scientific Name
871	Pink coral	*Pleurocorallium secundum*
873	Red coral	*Hemicorallium laauense*
881	Gold Coral	*Kulamanamana haumeaae* (prev. *Gerardia* spp.)
892	Bamboo coral	*Acanella* spp.

MONITORED ECOSYSTEM COMPONENT SPECIES

1. Species Selected for Monitoring by DLNR-DAR

DAR Species Code	Species Name	Scientific Name
18	bluefin trevally (omilu)	*Caranx melampygus*
47	whitemargin unicornfish (kala)	*Naso annulatus*
52	whitesaddle goatfish (kūmū)	*Parupeneus porphyus*
64	convict tang (manini)	*Acanthurus triostegus*

DAR Species Code	Species Name	Scientific Name
74	brown chub (nenue)	*Kyphosus bigibbus*
87/88/96	parrotfish (uhu)	Scaridae
114	bluestripe snapper (ta'ape)	*Lutjanus kasmira*
716/717/718	lobster	Miscellaneous
724	limpets ('opihi)	*Cellana* spp.
726	day octopus (day tako)	*Octopus cyanea*

2. Species Monitored by Tropic, Taxonomic, and Functional Groups

The species presented in Section 2.1 are displayed according to both trophic level and functional group as an effort to foster continued monitoring of ecosystem component species that are no longer categorized as management unit species. These species are monitored according to their ecosystem function as opposed to individually. Monitoring based on these factors allows for a broader outlook on the ecological composition of fish communities in areas of the Western Pacific. For trophic groupings, "H" stands for "Herbivore", "Cor" stands for "Corallivore", "PK" stands for "Planktivore", "MI" stands for "Mobile Invertebrate Feeder", "SI" stands for "Sessile-Invertebrate Feeder, "Om" stands for "Omnivore", and "Pisc" stands for "Piscovore".

Family	Scientific Name	Trophic Group	Functional Group
Acanthuridae	*Naso lituratus*	H	Browsing Surgeons
Acanthuridae	*Naso tonganus*	H	Browsing Surgeons
Acanthuridae	*Naso unicornis*	H	Browsing Surgeons
Acanthuridae	*Naso brachycentron*	H	Browsing Surgeons
Acanthuridae	*Ctenochaetus cyanocheilus*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus strigosus*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus nigroris*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus hawaiiensis*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus striatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Ctenochaetus marginatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus lineatus*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus blochii*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus dussumieri*	H	Mid-Large Target Surgeons
Acanthuridae	*Acanthurus xanthopterus*	H	Mid-Large Target Surgeons
Chaetodontidae	*Chaetodon flavocoronatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon multicinctus*	Cor	Non-PK Butterflyfish

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Chaetodontidae	*Chaetodon punctatofasciatus*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon mertensii*	H	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon citrinellus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon pelewensis*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lunulatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon melannotus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon rafflesii*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ulietensis*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon fremblii*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon quadrimaculatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon meyeri*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon reticulatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon trifascialis*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Heniochus chrysostomus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon bennetti*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon tinkeri*	SI	Non-PK Butterflyfish
Chaetodontidae	*Heniochus varius*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ornatissimus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon unimaculatus*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lunula*	SI	Non-PK Butterflyfish
Chaetodontidae	*Forcipiger longirostris*	MI	Non-PK Butterflyfish
Chaetodontidae	*Forcipiger flavissimus*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon ephippium*	MI	Non-PK Butterflyfish
Chaetodontidae	*Heniochus monoceros*	MI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon auriga*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon vagabundus*	SI	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon semeion*	H	Non-PK Butterflyfish
Chaetodontidae	*Chaetodontidae*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Heniochus singularius*	Cor	Non-PK Butterflyfish
Chaetodontidae	*Chaetodon lineolatus*	SI	Non-PK Butterflyfish
Caracanthidae	*Caracanthus typicus*	MI	No Group
Gobiidae	*Eviota* sp.	MI	No Group
Pomacentridae	*Chrysiptera traceyi*	H	No Group
Apogonidae	*Ostorhinchus luteus*	Pk	No Group
Caracanthidae	*Caracanthus maculatus*	MI	No Group
Pseudochromidae	*Pseudochromis jamesi*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacentridae	*Chromis acares*	Pk	No Group
Serranidae	*Luzonichthys whitleyi*	Pk	No Group
Pomacentridae	*Pomachromis guamensis*	Pk	No Group
Pomacentridae	*Pomachromis richardsoni*	Pk	No Group
Gobiidae	*Fusigobius duospilus*	MI	No Group
Pomacentridae	*Plectroglyphidodon imparipennis*	MI	No Group
Microdesmidae	*Nemateleotris helfrichi*	Pk	No Group
Pomacentridae	*Chromis leucura*	Pk	No Group
Syngnathidae	*Doryrhamphus excisus*	Pk	No Group
Pomacentridae	*Pomacentrus coelestis*	Pk	No Group
Clupeidae	*Spratelloides delicatulus*	Pk	No Group
Pomacentridae	*Chrysiptera biocellata*	H	No Group
Pseudochromidae	*Pictichromis porphyreus*	MI	No Group
Pomacanthidae	*Centropyge fisheri*	H	No Group
Cirrhitidae	*Cirrhitops hubbardi*	MI	No Group
Gobiidae	*Amblyeleotris fasciata*	Pk	No Group
Pomacentridae	*Chromis lepidolepis*	Pk	No Group
Pomacentridae	*Chromis margaritifer*	Pk	No Group
Pomacentridae	*Chromis ternatensis*	Pk	No Group
Pomacentridae	*Chromis viridis*	Pk	No Group
Pomacentridae	*Chrysiptera cyanea*	Pk	No Group
Pomacentridae	*Dascyllus aruanus*	Pk	No Group
Pomacentridae	*Dascyllus reticulatus*	Pk	No Group
Engraulidae	*Encrasicholina purpurea*	Pk	No Group
Pomacentridae	*Neopomacentrus metallicus*	Pk	No Group
Pomacentridae	*Chromis amboinensis*	H	No Group
Pomacentridae	*Chromis iomelas*	H	No Group
Pomacentridae	*Chrysiptera glauca*	H	No Group
Pomacentridae	*Chrysiptera taupou*	H	No Group
Labridae	*Labroides pectoralis*	MI	No Group
Labridae	*Pseudocheilinus hexataenia*	MI	No Group
Labridae	*Pseudocheilinus tetrataenia*	MI	No Group
Scorpaenidae	*Sebastapistes cyanostigma*	MI	No Group
Labridae	*Wetmorella nigropinnata*	MI	No Group
Pseudochromidae	*Pseudochromis* sp.	MI	No Group
Monacanthidae	*Pervagor marginalis*	Om	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacentridae	*Chromis alpha*	Pk	No Group
Pomacentridae	*Plectroglyphidodon phoenixensis*	H	No Group
Gobiidae	*Amblyeleotris guttata*	Pk	No Group
Atherinidae	*Atherinomorus insularum*	Pk	No Group
Pomacentridae	*Chromis caudalis*	Pk	No Group
Pomacentridae	*Chromis hanui*	Pk	No Group
Labridae	*Cirrhilabrus katherinae*	Pk	No Group
Microdesmidae	*Nemateleotris magnifica*	Pk	No Group
Apogonidae	*Ostorhinchus angustatus*	Pk	No Group
Serranidae	*Pseudanthias bartlettorum*	Pk	No Group
Tetraodontidae	*Canthigaster jactator*	H	No Group
Tetraodontidae	*Canthigaster janthinoptera*	H	No Group
Tetraodontidae	*Canthigaster valentini*	H	No Group
Pomacanthidae	*Centropyge shepardi*	H	No Group
Pomacentridae	*Chrysiptera brownriggii*	H	No Group
Monacanthidae	*Oxymonacanthus longirostris*	Cor	No Group
Cirrhitidae	*Amblycirrhitus bimacula*	MI	No Group
Cirrhitidae	*Cirrhitichthys falco*	MI	No Group
Labridae	*Labroides rubrolabiatus*	MI	No Group
Cirrhitidae	*Neocirrhites armatus*	MI	No Group
Labridae	*Pseudojuloides splendens*	MI	No Group
Apogonidae	*Ostorhinchus novemfasciatus*	Pk	No Group
Labridae	*Pteragogus cryptus*	MI	No Group
Scorpaenidae	*Sebastapistes* sp.	Pisc	No Group
Scorpaenidae	*Taenianotus triacanthus*	Pisc	No Group
Pomacentridae	*Amphiprion perideraion*	Pk	No Group
Pomacentridae	*Chromis fumea*	Pk	No Group
Labridae	*Cirrhilabrus jordani*	Pk	No Group
Blenniidae	*Ecsenius bicolor*	Pk	No Group
Blenniidae	*Ecsenius midas*	Pk	No Group
Blenniidae	*Ecsenius opsifrontalis*	Pk	No Group
Pomacentridae	*Lepidozygus tapeinosoma*	Pk	No Group
Blenniidae	*Meiacanthus atrodorsalis*	Pk	No Group
Apogonidae	*Ostorhinchus apogonoides*	Pk	No Group

Family	Scientific Name	Trophic Group	Functional Group
Pomacentridae	*Plectroglyphidodon lacrymatus*	Pk	No Group
Pomacentridae	*Pomacentrus brachialis*	Pk	No Group
Pomacentridae	*Pomacentrus nigriradiatus*	Pk	No Group
Pomacentridae	*Pomacentrus philippinus*	Pk	No Group
Pomacentridae	*Pomacentrus vaiuli*	Pk	No Group
Serranidae	*Pseudanthias dispar*	Pk	No Group
Serranidae	*Pseudanthias hawaiiensis*	Pk	No Group
Tetraodontidae	*Canthigaster bennetti*	H	No Group
Pomacanthidae	*Centropyge bispinosa*	H	No Group
Pomacanthidae	*Centropyge heraldi*	H	No Group
Pomacanthidae	*Centropyge loricula*	H	No Group
Blenniidae	*Cirripectes obscurus*	H	No Group
Blenniidae	*Cirripectes polyzona*	H	No Group
Blenniidae	*Cirripectes* sp.	H	No Group
Blenniidae	*Cirripectes springeri*	H	No Group
Blenniidae	*Cirripectes stigmaticus*	H	No Group
Blenniidae	*Cirripectes variolosus*	H	No Group
Callionymidae	*Callionymidae*	MI	No Group
Labridae	*Labroides phthirophagus*	MI	No Group
Pomacanthidae	*Paracentropyge multifasciata*	MI	No Group
Blenniidae	*Plagiotremus ewaensis*	MI	No Group
Blenniidae	*Plagiotremus goslinei*	MI	No Group
Scorpaenidae	*Sebastapistes coniorta*	MI	No Group
Monacanthidae	*Pervagor melanocephalus*	Om	No Group
Blenniidae	*Plagiotremus laudandus*	Par	No Group
Blenniidae	*Plagiotremus rhinorhynchos*	Par	No Group
Blenniidae	*Plagiotremus tapeinosoma*	Par	No Group
Labridae	*Pseudocheilinus ocellatus*	MI	No Group
Pomacanthidae	*Centropyge flavissima* & *vroliki*	H	No Group
Pomacentridae	*Amblyglyphidodon curacao*	Om	No Group
Pomacentridae	*Amphiprion melanopus*	Pk	No Group
Pomacentridae	*Chromis agilis*	Pk	No Group
Gobiidae	*Istigobius* sp.	Pk	No Group
Pomacentridae	*Pomacentrus pavo*	Pk	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Apogonidae	*Pristiapogon fraenatus*	Pk	No Group
Tetraodontidae	*Canthigaster epilampra*	H	No Group
Tetraodontidae	*Canthigaster solandri*	H	No Group
Blenniidae	*Cirripectes vanderbilti*	H	No Group
Pomacentridae	*Stegastes albifasciatus*	H	No Group
Pomacentridae	*Stegastes aureus*	H	No Group
Pomacentridae	*Stegastes marginatus*	H	No Group
Pomacentridae	*Plectroglyphidodon dickii*	Cor	No Group
Cirrhitidae	*Paracirrhites xanthus*	MI	No Group
Monacanthidae	*Paraluteres prionurus*	MI	No Group
Microdesmidae	*Microdesmidae*	Pk	No Group
Scorpaenidae	*Sebastapistes ballieui*	MI	No Group
Apogonidae	*Apogon kallopterus*	Pk	No Group
Pomacentridae	*Chromis weberi*	Pk	No Group
Labridae	*Cirrhilabrus exquisitus*	Pk	No Group
Syngnathidae	*Corythoichthys flavofasciatus*	Pk	No Group
Pomacentridae	*Dascyllus albisella*	Pk	No Group
Microdesmidae	*Gunnellichthys curiosus*	Pk	No Group
Apogonidae	*Pristiapogon kallopterus*	Pk	No Group
Serranidae	*Pseudanthias olivaceus*	Pk	No Group
Ptereleotridae	*Ptereleotris heteroptera*	Pk	No Group
Ptereleotridae	*Ptereleotris zebra*	Pk	No Group
Pomacanthidae	*Centropyge vrolikii*	H	No Group
Pomacentridae	*Plectroglyphidodon leucozonus*	H	No Group
Pomacentridae	*Plectroglyphidodon johnstonianus*	Cor	No Group
Labridae	*Anampses melanurus*	MI	No Group
Apogonidae	*Cheilodipterus quinquelineatus*	MI	No Group
Cirrhitidae	*Cirrhitichthys oxycephalus*	MI	No Group
Cirrhitidae	*Cirrhitops fasciatus*	MI	No Group
Labridae	*Halichoeres biocellatus*	MI	No Group
Labridae	*Labroides dimidiatus*	MI	No Group
Labridae	*Labropsis micronesica*	MI	No Group
Labridae	*Macropharyngodon negrosensis*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Labridae	*Pseudojuloides cerasinus*	MI	No Group
Labridae	*Pseudojuloides polynesica*	MI	No Group
Blenniidae	*Aspidontus taeniatus*	Par	No Group
Tetraodontidae	*Torquigener randalli*	MI	No Group
Pomacentridae	*Plectroglyphidodon sindonis*	H	No Group
Pomacanthidae	*Centropyge potteri*	H	No Group
Cirrhitidae	*Oxycirrhites typus*	Pk	No Group
Serranidae	*Pseudanthias bicolor*	Pk	No Group
Ptereleotridae	*Ptereleotris microlepis*	Pk	No Group
Pomacentridae	*Stegastes lividus*	H	No Group
Labridae	*Cirrhilabrus punctatus*	MI	No Group
Labridae	*Halichoeres margaritaceus*	MI	No Group
Labridae	*Pseudojuloides atavai*	MI	No Group
Holocentridae	*Sargocentron punctatissimum*	MI	No Group
Monacanthidae	*Pervagor janthinosoma*	Om	No Group
Pomacentridae	*Amphiprion clarkii*	Pk	No Group
Serranidae	*Anthias* sp.	Pk	No Group
Blenniidae	*Blenniella chrysospilos*	Pk	No Group
Chaetodontidae	*Chaetodon kleinii*	Pk	No Group
Pomacentridae	*Dascyllus trimaculatus*	Pk	No Group
Apogonidae	*Ostorhinchus maculiferus*	Pk	No Group
Serranidae	*Pseudanthias cooperi*	Pk	No Group
Gobiidae	*Amblygobius phalaena*	H	No Group
Tetraodontidae	*Canthigaster amboinensis*	H	No Group
Tetraodontidae	*Canthigaster coronata*	H	No Group
Pomacanthidae	*Centropyge flavissima*	H	No Group
Pomacentridae	*Stegastes nigricans*	H	No Group
Labridae	*Halichoeres melanurus*	MI	No Group
Labridae	*Halichoeres melasmapomus*	MI	No Group
Labridae	*Labroides bicolor*	MI	No Group
Labridae	*Labropsis xanthonota*	MI	No Group
Cirrhitidae	*Paracirrhites arcatus*	MI	No Group
Labridae	*Pseudocheilinus evanidus*	MI	No Group
Labridae	*Pseudocheilinus octotaenia*	MI	No Group
Monacanthidae	*Pervagor aspricaudus*	Om	No Group
Ostraciidae	*Lactoria fornasini*	SI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Labridae	*Pseudojuloides* sp.	MI	No Group
Pomacentridae	*Abudefduf sexfasciatus*	Pk	No Group
Pomacentridae	*Chromis vanderbilti*	Pk	No Group
Pomacentridae	*Chromis xanthura*	Pk	No Group
Labridae	*Cirrhilabrus* sp.	Pk	No Group
Pomacanthidae	*Genicanthus watanabei*	Pk	No Group
Labridae	*Thalassoma amblycephalum*	Pk	No Group
Pomacanthidae	*Centropyge bicolor*	H	No Group
Serranidae	*Belonoperca chabanaudi*	MI	No Group
Labridae	*Coris centralis*	MI	No Group
Labridae	*Halichoeres ornatissimus*	MI	No Group
Malacanthidae	*Hoplolatilus starcki*	MI	No Group
Labridae	*Macropharyngodon meleagris*	MI	No Group
Labridae	*Oxycheilinus bimaculatus*	MI	No Group
Labridae	*Pteragogus enneacanthus*	MI	No Group
Labridae	*Stethojulis balteata*	MI	No Group
Labridae	*Stethojulis strigiventer*	MI	No Group
Labridae	*Stethojulis trilineata*	MI	No Group
Pomacentridae	*Stegastes* sp.	H	No Group
Apogonidae	*Apogon* sp.	Pk	No Group
Apogonidae	*Apogonidae*	Pk	No Group
Chaetodontidae	*Chaetodon miliaris*	Pk	No Group
Pomacentridae	*Dascyllus auripinnis*	Pk	No Group
Labridae	*Pseudocoris yamashiroi*	Pk	No Group
Labridae	*Stethojulis bandanensis*	Pk	No Group
Monacanthidae	*Cantherhines verecundus*	H	No Group
Pomacanthidae	*Centropyge interrupta*	H	No Group
Pomacentridae	*Stegastes fasciolatus*	H	No Group
Blenniidae	*Exallias brevis*	Cor	No Group
Labridae	*Labrichthys unilineatus*	Cor	No Group
Labridae	*Halichoeres prosopeion*	MI	No Group
Labridae	*Macropharyngodon geoffroy*	MI	No Group
Gobiidae	*Valenciennea strigata*	MI	No Group
Ostraciidae	*Ostracion whitleyi*	SI	No Group
Scorpaenidae	*Dendrochirus barberi*	MI	No Group
Blenniidae	*Blenniidae*	Pk	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Synodontidae	*Synodus binotatus*	Pisc	No Group
Pomacentridae	*Amphiprion chrysopterus*	Pk	No Group
Serranidae	*Pseudanthias pascalus*	Pk	No Group
Acanthuridae	*Ctenochaetus flavicauda*	H	No Group
Labridae	*Cheilinus oxycephalus*	MI	No Group
Holocentridae	*Sargocentron diadema*	MI	No Group
Holocentridae	*Sargocentron xantherythrum*	MI	No Group
Labridae	*Thalassoma quinquevittatum*	MI	No Group
Labridae	*Iniistius umbrilatus*	MI	No Group
Labridae	*Thalassoma* sp.	MI	No Group
Pomacentridae	*Pomacentridae*	Om	No Group
Pomacentridae	*Abudefduf notatus*	Pk	No Group
Chaetodontidae	*Hemitaurichthys polylepis*	Pk	No Group
Ptereleotridae	*Ptereleotris evides*	Pk	No Group
Labridae	*Anampses twistii*	MI	No Group
Apogonidae	*Cheilodipterus* sp.	MI	No Group
Labridae	*Cymolutes lecluse*	MI	No Group
Labridae	*Halichoeres hartzfeldii*	MI	No Group
Labridae	*Halichoeres marginatus*	MI	No Group
Pinguipedidae	*Parapercis clathrata*	MI	No Group
Pinguipedidae	*Parapercis schauinslandii*	MI	No Group
Labridae	*Choerodon jordani*	Om	No Group
Monacanthidae	*Pervagor* sp.	Om	No Group
Monacanthidae	*Pervagor spilosoma*	Om	No Group
Pomacanthidae	*Apolemichthys arcuatus*	SI	No Group
Holocentridae	*Neoniphon argenteus*	MI	No Group
Apogonidae	*Cheilodipterus artus*	MI	No Group
Pomacentridae	*Chromis ovalis*	Pk	No Group
Labridae	*Bodianus mesothorax*	MI	No Group
Pinguipedidae	*Parapercis millepunctata*	MI	No Group
Labridae	*Halichoeres* sp.	MI	No Group
Serranidae	*Cephalopholis leopardus*	Pisc	No Group
Apogonidae	*Cheilodipterus macrodon*	Pisc	No Group
Pomacentridae	*Abudefduf vaigiensis*	Pk	No Group
Chaetodontidae	*Heniochus diphreutes*	Pk	No Group
Holocentridae	*Myripristis vittata*	Pk	No Group

Family	Scientific Name	Trophic Group	Functional Group
Caesionidae	*Pterocaesio trilineata*	Pk	No Group
Labridae	*Thalassoma hardwicke*	Pk	No Group
Monacanthidae	*Cantherhines sandwichiensis*	H	No Group
Tetraodontidae	*Canthigaster rivulata*	H	No Group
Acanthuridae	*Zebrasoma flavescens*	H	No Group
Acanthuridae	*Zebrasoma scopas*	H	No Group
Monacanthidae	*Amanses scopas*	Cor	No Group
Labridae	*Anampses chrysocephalus*	MI	No Group
Labridae	*Anampses* sp.	MI	No Group
Labridae	*Bodianus axillaris*	MI	No Group
Labridae	*Bodianus prognathus*	MI	No Group
Labridae	*Coris dorsomacula*	MI	No Group
Labridae	*Coris venusta*	MI	No Group
Labridae	*Cymolutes praetextatus*	MI	No Group
Labridae	*Pseudocoris aurantiofasciata*	MI	No Group
Labridae	*Pseudocoris heteroptera*	MI	No Group
Scorpaenidae	*Pterois antennata*	MI	No Group
Holocentridae	*Sargocentron microstoma*	MI	No Group
Labridae	*Thalassoma jansenii*	MI	No Group
Nemipteridae	*Scolopsis lineata*	Om	No Group
Zanclidae	*Zanclus cornutus*	SI	No Group
Labridae	*Bodianus anthioides*	Pk	No Group
Chaetodontidae	*Hemitaurichthys thompsoni*	Pk	No Group
Acanthuridae	*Zebrasoma rostratum*	H	No Group
Kuhliidae	*Kuhlia sandvicensis*	Pk	No Group
Scorpaenidae	*Pterois sphex*	Pisc	No Group
Synodontidae	*Synodontidae*	Pisc	No Group
Pomacentridae	*Chromis verater*	Pk	No Group
Pempheridae	*Pempheridae*	Pk	No Group
Serranidae	*Pseudanthias thompsoni*	Pk	No Group
Balistidae	*Xanthichthys auromarginatus*	Pk	No Group
Acanthuridae	*Ctenochaetus binotatus*	H	No Group
Labridae	*Anampses meleagrides*	MI	No Group
Labridae	*Iniistius aneitensis*	MI	No Group
Mullidae	*Parupeneus chrysonemus*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Balistidae	*Sufflamen chrysopterum*	MI	No Group
Cirrhitidae	*Paracirrhites forsteri*	Pisc	No Group
Synodontidae	*Saurida gracilis*	Pisc	No Group
Holocentridae	*Myripristis kuntee*	Pk	No Group
Pempheridae	*Pempheris oualensis*	Pk	No Group
Pomacentridae	*Abudefduf septemfasciatus*	H	No Group
Acanthuridae	*Acanthurus nigricans*	H	No Group
Acanthuridae	*Acanthurus nigrofuscus*	H	No Group
Holocentridae	*Neoniphon aurolineatus*	MI	No Group
Pinguipedidae	*Parapercis* sp.	MI	No Group
Labridae	*Bodianus sanguineus*	Om	No Group
Synodontidae	*Synodus dermatogenys*	Pisc	No Group
Synodontidae	*Synodus variegatus*	Pisc	No Group
Pomacentridae	*Abudefduf sordidus*	H	No Group
Holocentridae	*Myripristis earlei*	MI	No Group
Pomacentridae	*Abudefduf abdominalis*	Pk	No Group
Pomacanthidae	*Genicanthus personatus*	Pk	No Group
Chaetodontidae	*Heniochus acuminatus*	Pk	No Group
Holocentridae	*Myripristis chryseres*	Pk	No Group
Holocentridae	*Myripristis woodsi*	Pk	No Group
Labridae	*Thalassoma lunare*	Pk	No Group
Acanthuridae	*Acanthurus achilles*	H	No Group
Acanthuridae	*Acanthurus achilles* & *nigricans*	H	No Group
Acanthuridae	*Acanthurus leucopareius*	H	No Group
Acanthuridae	*Acanthurus pyroferus*	H	No Group
Monacanthidae	*Cantherhines pardalis*	H	No Group
Labridae	*Bodianus diana*	MI	No Group
Balistidae	*Rhinecanthus rectangulus*	MI	No Group
Holocentridae	*Sargocentron caudimaculatum*	MI	No Group
Holocentridae	*Sargocentron ensifer*	MI	No Group
Labridae	*Thalassoma duperrey* & *quinquevittatum*	MI	No Group
Labridae	*Thalassoma lutescens*	MI	No Group
Pomacanthidae	*Apolemichthys griffisi*	SI	No Group
Pomacanthidae	*Apolemichthys trimaculatus*	SI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Pomacanthidae	*Apolemichthys xanthopunctatus*	SI	No Group
Pomacanthidae	*Pygoplites diacanthus*	SI	No Group
Serranidae	*Epinephelus hexagonatus*	Pisc	No Group
Acanthuridae	*Acanthurus nubilus*	Pk	No Group
Muraenidae	*Gymnothorax melatremus*	MI	No Group
Labridae	*Pseudodax moluccanus*	MI	No Group
Labridae	*Thalassoma duperrey*	MI	No Group
Acanthuridae	*Acanthurus triostegus*	H	No Group
Serranidae	*Grammistes sexlineatus*	MI	No Group
Labridae	*Halichoeres hortulanus*	MI	No Group
Labridae	*Halichoeres trimaculatus*	MI	No Group
Serranidae	*Cephalopholis urodeta*	Pisc	No Group
Cirrhitidae	*Paracirrhites hemistictus*	Pisc	No Group
Acanthuridae	*Acanthurus thompsoni*	Pk	No Group
Siganidae	*Siganus spinus*	H	No Group
Balistidae	*Rhinecanthus lunula*	MI	No Group
Balistidae	*Sufflamen bursa*	MI	No Group
Ostraciidae	*Ostracion meleagris*	SI	No Group
Acanthuridae	*Acanthurus guttatus*	H	No Group
Cirrhitidae	*Cirrhitidae*	MI	No Group
Serranidae	*Cephalopholis spiloparaea*	Pisc	No Group
Labridae	*Oxycheilinus digramma*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis diabolus*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis* sp.	Pisc	No Group
Synodontidae	*Synodus ulae*	Pisc	No Group
Caesionidae	*Caesio lunaris*	Pk	No Group
Balistidae	*Canthidermis maculata*	Pk	No Group
Hemiramphidae	*Hyporhamphus acutus*	Pk	No Group
Caesionidae	*Pterocaesio lativittata*	Pk	No Group
Caesionidae	*Pterocaesio tile*	Pk	No Group
Carangidae	*Selar crumenophthalmus*	Pk	No Group
Balistidae	*Xanthichthys mento*	Pk	No Group
Acanthuridae	*Ctenochaetus* sp.	H	No Group
Acanthuridae	*Naso thynnoides*	H	No Group
Balistidae	*Balistapus undulatus*	MI	No Group
Cirrhitidae	*Cirrhitus pinnulatus*	MI	No Group

Family	Scientific Name	Trophic Group	Functional Group
Labridae	*Coris ballieui*	MI	No Group
Lethrinidae	*Gnathodentex aureolineatus*	MI	No Group
Malacanthidae	*Malacanthus brevirostris*	MI	No Group
Mullidae	*Mulloidichthys mimicus*	MI	No Group
Holocentridae	*Myripristis violacea*	MI	No Group
Labridae	*Novaculichthys taeniourus*	MI	No Group
Balistidae	*Rhinecanthus aculeatus*	MI	No Group
Synodontidae	*Saurida flamma*	Pisc	No Group
Acanthuridae	*Paracanthurus hepatus*	Pk	No Group
Caesionidae	*Caesionidae*	Pk	No Group
Holocentridae	*Holocentridae*	MI	No Group
Priacanthidae	*Heteropriacanthus carolinus*	Pk	No Group
Holocentridae	*Myripristis adusta*	Pk	No Group
Holocentridae	*Myripristis amaena*	Pk	No Group
Labridae	*Cheilinus chlorourus*	MI	No Group
Labridae	*Gomphosus varius*	MI	No Group
Lethrinidae	*Lethrinus harak*	MI	No Group
Holocentridae	*Neoniphon sammara*	MI	No Group
Serranidae	*Epinephelus melanostigma*	Pisc	No Group
Serranidae	*Epinephelus merra*	Pisc	No Group
Holocentridae	*Myripristis berndti*	Pk	No Group
Priacanthidae	*Priacanthus hamrur*	Pk	No Group
Priacanthidae	*Priacanthus meeki*	Pk	No Group
Acanthuridae	*Acanthurus albipectoralis*	H	No Group
Tetraodontidae	*Arothron nigropunctatus*	Cor	No Group
Mullidae	*Parupeneus insularis*	MI	No Group
Mullidae	*Parupeneus pleurostigma*	MI	No Group
Holocentridae	*Sargocentron tiere*	MI	No Group
Labridae	*Thalassoma trilobatum*	MI	No Group
Mullidae	*Upeneus taeniopterus*	MI	No Group
Balistidae	*Melichthys vidua*	H	No Group
Serranidae	*Epinephelus spilotoceps*	Pisc	No Group
Lutjanidae	*Lutjanus semicinctus*	Pisc	No Group
Serranidae	*Pogonoperca punctata*	Pisc	No Group
Caesionidae	*Caesio caerulaurea*	Pk	No Group
Carangidae	*Decapterus macarellus*	Pk	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Holocentridae	*Myripristinae*	Pk	No Group
Caesionidae	*Pterocaesio marri*	Pk	No Group
Balistidae	*Xanthichthys caeruleolineatus*	Pk	No Group
Labridae	*Iniistius pavo*	MI	No Group
Holocentridae	*Neoniphon opercularis*	MI	No Group
Holocentridae	*Neoniphon* sp.	MI	No Group
Mullidae	*Parupeneus crassilabris*	MI	No Group
Labridae	*Anampses cuvier*	MI	No Group
Labridae	*Cheilinus fasciatus*	MI	No Group
Siganidae	*Siganus punctatus*	H	No Group
Gobiidae	*Gobiidae*	MI	No Group
Scorpaenidae	*Pterois volitans*	Pisc	No Group
Balistidae	*Melichthys niger*	Pk	No Group
Priacanthidae	*Priacanthus* sp.	Pk	No Group
Monacanthidae	*Monacanthidae*	H	No Group
Siganidae	*Siganidae*	H	No Group
Diodontidae	*Diodon holocanthus*	MI	No Group
Mullidae	*Mulloidichthys vanicolensis*	MI	No Group
Mullidae	*Parupeneus multifasciatus*	MI	No Group
Balistidae	*Sufflamen fraenatum*	MI	No Group
Monacanthidae	*Cantherhines dumerilii*	Om	No Group
Pomacanthidae	*Pomacanthus imperator*	SI	No Group
Lethrinidae	*Lethrinus rubrioperculatus*	MI	No Group
Caesionidae	*Caesio teres*	Pk	No Group
Balistidae	*Odonus niger*	Pk	No Group
Acanthuridae	*Acanthurus nigricauda*	H	No Group
Acanthuridae	*Acanthurus olivaceus*	H	No Group
Acanthuridae	*Zebrasoma veliferum*	H	No Group
Labridae	*Bodianus loxozonus*	MI	No Group
Labridae	*Coris gaimard*	MI	No Group
Labridae	*Hologymnosus annulatus*	MI	No Group
Labridae	*Hologymnosus doliatus*	MI	No Group
Mullidae	*Mulloidichthys flavolineatus*	MI	No Group
Acanthuridae	*Acanthurus maculiceps*	H	No Group
Kyphosidae	*Kyphosus hawaiiensis*	H	No Group
Cheilodactylidae	*Cheilodactylus vittatus*	SI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Ostraciidae	*Ostraciidae*	SI	No Group
Siganidae	*Siganus argenteus*	H	No Group
Labridae	*Anampses caeruleopunctatus*	MI	No Group
Serranidae	*Epinephelus fasciatus*	Pisc	No Group
Labridae	*Thalassoma ballieui*	MI	No Group
Labridae	*Thalassoma purpureum*	MI	No Group
Serranidae	*Cephalopholis miniata*	Pisc	No Group
Hemiramphidae	*Hemiramphidae*	Pk	No Group
Acanthuridae	*Acanthurus leucocheilus*	H	No Group
Ostraciidae	*Ostracion cubicus*	H	No Group
Bothidae	*Bothus mancus*	MI	No Group
Labridae	*Cheilinus* sp.	MI	No Group
Labridae	*Cheilinus trilobatus*	MI	No Group
Malacanthidae	*Malacanthus latovittatus*	MI	No Group
Labridae	*Oxycheilinus unifasciatus*	Pisc	No Group
Labridae	*Oxycheilinus* sp.	MI	No Group
Serranidae	*Epinephelus retouti*	Pisc	No Group
Mullidae	*Mulloidichthys pfluegeri*	MI	No Group
Serranidae	*Cephalopholis sexmaculata*	Pisc	No Group
Serranidae	*Cephalopholis sonnerati*	Pisc	No Group
Serranidae	*Gracila albomarginata*	Pisc	No Group
Mullidae	*Parupeneus cyclostomus*	Pisc	No Group
Belonidae	*Platybelone argalus*	Pisc	No Group
Acanthuridae	*Acanthurus mata*	Pk	No Group
Tetraodontidae	*Arothron meleagris*	Cor	No Group
Balistidae	*Balistoides conspicillum*	MI	No Group
Labridae	*Hemigymnus fasciatus*	MI	No Group
Lethrinidae	*Lethrinus obsoletus*	MI	No Group
Mullidae	*Mullidae*	MI	No Group
Mullidae	*Parupeneus barberinus*	MI	No Group
Holocentridae	*Sargocentron* sp.	MI	No Group
Ephippidae	*Platax orbicularis*	Om	No Group
Serranidae	*Epinephelus macrospilos*	Pisc	No Group
Scorpaenidae	*Scorpaenopsis cacopsis*	Pisc	No Group
Kyphosidae	*Kyphosus cinerascens*	H	No Group
Labridae	*Cheilio inermis*	MI	No Group

Family	Scientific Name	Trophic Group	Functional Group
Mullidae	*Parupeneus porphyreus*	MI	No Group
Serranidae	*Epinephelus socialis*	Pisc	No Group
Tetraodontidae	*Arothron hispidus*	MI	No Group
Holocentridae	*Sargocentron spiniferum*	MI	No Group
Carangidae	*Trachinotus baillonii*	Pisc	No Group
Labridae	*Epibulus insidiator*	MI	No Group
Serranidae	*Epinephelus howlandi*	Pisc	No Group
Labridae	*Bodianus albotaeniatus*	MI	No Group
Labridae	*Bodianus bilunulatus*	MI	No Group
Acanthuridae	*Acanthurus* sp.	H	No Group
Serranidae	*Aethaloperca rogaa*	Pisc	No Group
Serranidae	*Anyperodon leucogrammicus*	Pisc	No Group
Serranidae	*Cephalopholis argus*	Pisc	No Group
Serranidae	*Cephalopholis* sp.	Pisc	No Group
Serranidae	*Epinephelus maculatus*	Pisc	No Group
Holocentridae	*Myripristis murdjan*	Pk	No Group
Acanthuridae	*Naso brevirostris*	Pk	No Group
Acanthuridae	*Naso maculatus*	Pk	No Group
Acanthuridae	*Naso vlamingii*	Pk	No Group
Kyphosidae	*Kyphosus vaigiensis*	H	No Group
Muraenidae	*Gymnothorax eurostus*	MI	No Group
Labridae	*Hemigymnus melapterus*	MI	No Group
Balistidae	*Pseudobalistes flavimarginatus*	MI	No Group
Lethrinidae	*Lethrinus xanthochilus*	Pisc	No Group
Acanthuridae	*Naso caesius*	Pk	No Group
Lethrinidae	*Monotaxis grandoculis*	MI	No Group
Serranidae	*Variola albimarginata*	Pisc	No Group
Labridae	*Coris flavovittata*	MI	No Group
Tetraodontidae	*Arothron mappa*	Om	No Group
Carangidae	*Carangoides ferdau*	Pisc	No Group
Carangidae	*Carangoides orthogrammus*	Pisc	No Group
Carangidae	*Scomberoides lysan*	Pisc	No Group
Acanthuridae	*Acanthuridae*	H	No Group
Lethrinidae	*Lethrinus amboinensis*	MI	No Group
Lethrinidae	*Lethrinus erythracanthus*	MI	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Ephippidae	*Platax teira*	Om	No Group
Serranidae	*Plectropomus areolatus*	Pisc	No Group
Carangidae	*Gnathanodon speciosus*	Pisc	No Group
Serranidae	*Epinephelus polyphekadion*	Pisc	No Group
Serranidae	*Epinephelus tauvina*	Pisc	No Group
Muraenidae	*Gymnothorax breedeni*	Pisc	No Group
Acanthuridae	*Naso hexacanthus*	Pk	No Group
Acanthuridae	*Naso* sp.	Pk	No Group
Kyphosidae	*Kyphosus sandwicensis*	H	No Group
Kyphosidae	*Kyphosus* sp.	H	No Group
Balistidae	*Balistidae*	MI	No Group
Balistidae	*Balistoides viridescens*	MI	No Group
Muraenidae	*Echidna nebulosa*	MI	No Group
Haemulidae	*Plectorhinchus gibbosus*	MI	No Group
Balistidae	*Balistes polylepis*	MI	No Group
Tetraodontidae	*Tetraodontidae*	MI	No Group
Monacanthidae	*Aluterus scriptus*	Om	No Group
Ophichthidae	*Myrichthys magnificus*	MI	No Group
Aulostomidae	*Aulostomus chinensis*	Pisc	No Group
Muraenidae	*Enchelycore pardalis*	Pisc	No Group
Sphyraenidae	*Sphyraena helleri*	Pisc	No Group
Muraenidae	*Gymnothorax rueppelliae*	MI	No Group
Oplegnathidae	*Oplegnathus fasciatus*	MI	No Group
Serranidae	*Variola louti*	Pisc	No Group
Haemulidae	*Plectorhinchus picus*	MI	No Group
Haemulidae	*Plectorhinchus vittatus*	MI	No Group
Lethrinidae	*Lethrinidae*	MI	No Group
Lethrinidae	*Lethrinus* sp.	MI	No Group
Oplegnathidae	*Oplegnathus punctatus*	MI	No Group
Carangidae	*Caranx papuensis*	Pisc	No Group
Muraenidae	*Gymnothorax steindachneri*	Pisc	No Group
Diodontidae	*Diodon hystrix*	MI	No Group
Labridae	*Labridae*	MI	No Group
Belonidae	*Belonidae*	Pisc	No Group
Carangidae	*Caranx lugubris*	Pisc	No Group
Carangidae	*Caranx sexfasciatus*	Pisc	No Group

Family	Scientific Name	Trophic Group	Functional Group
Scombridae	*Euthynnus affinis*	Pisc	No Group
Scombridae	*Grammatorcynus bilineatus*	Pisc	No Group
Lethrinidae	*Lethrinus olivaceus*	Pisc	No Group
Acanthuridae	*Naso annulatus*	Pk	No Group
Ophidiidae	*Brotula multibarbata*	MI	No Group
Dasyatidae	*Urogymnus granulatus*	MI	No Group
Scombridae	*Sarda orientalis*	Pisc	No Group
Congridae	*Congridae*	Pisc	No Group
Congridae	*Heterocongrinae*	Pisc	No Group
Scombridae	*Katsuwonus pelamis*	Pisc	No Group
Echeneidae	*Echeneis naucrates*	Pk	No Group
Carangidae	*Trachinotus blochii*	MI	No Group
Carangidae	*Caranx melampygus*	Pisc	No Group
Muraenidae	*Gymnothorax meleagris*	Pisc	No Group
Tetraodontidae	*Arothron stellatus*	Cor	No Group
Labridae	*Coris aygula*	MI	No Group
Carangidae	*Pseudocaranx dentex*	Pisc	No Group
Muraenidae	*Scuticaria tigrina*	Pisc	No Group
Serranidae	*Plectropomus laevis*	Pisc	No Group
Serranidae	*Epinephelus* sp.	Pisc	No Group
Serranidae	*Serranidae*	Pisc	No Group
Belonidae	*Tylosurus crocodilus*	Pisc	No Group
Carangidae	*Alectis ciliaris*	Pisc	No Group
Muraenidae	*Enchelynassa canina*	Pisc	No Group
Muraenidae	*Gymnothorax undulatus*	Pisc	No Group
Muraenidae	*Gymnomuraena zebra*	MI	No Group
Carangidae	*Carangidae*	Pisc	No Group
Fistulariidae	*Fistularia commersonii*	Pisc	No Group
Carangidae	*Caranx ignobilis*	Pisc	No Group
Carangidae	*Caranx* sp.	Pisc	No Group
Sphyraenidae	*Sphyraena qenie*	Pisc	No Group
Carangidae	*Elagatis bipinnulata*	Pisc	No Group
Chanidae	*Chanos chanos*	H	No Group
Dasyatidae	*Taeniurops meyeni*	MI	No Group
Dasyatidae	*Dasyatidae*	MI	No Group
Carangidae	*Seriola dumerili*	Pisc	No Group

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Carcharhinidae	*Carcharhinus melanopterus*	Pisc	No Group
Sphyraenidae	*Sphyraena barracuda*	Pisc	No Group
Scombridae	*Thunnus albacares*	Pisc	No Group
Carcharhinidae	*Triaenodon obesus*	Pisc	No Group
Labridae	*Cheilinus undulatus*	MI	No Group
Carcharhinidae	*Carcharhinus amblyrhynchos*	Pisc	No Group
Muraenidae	*Gymnothorax flavimarginatus*	Pisc	No Group
Scombridae	*Scombridae*	Pisc	No Group
Scombridae	*Gymnosarda unicolor*	Pisc	No Group
Muraenidae	*Muraenidae*	Pisc	No Group
Carcharhinidae	*Carcharhinus limbatus*	Pisc	No Group
Muraenidae	*Gymnothorax javanicus*	Pisc	No Group
Muraenidae	*Gymnothorax* sp.	Pisc	No Group
Ginglymostomatidae	*Nebrius ferrugineus*	Pisc	No Group
Myliobatidae	*Aetobatus ocellatus*	MI	No Group
Carcharhinidae	*Carcharhinus galapagensis*	Pisc	No Group
Sphyrnidae	*Sphyrna lewini*	Pisc	No Group
Sphyrnidae	*Sphyrnidae*	Pisc	No Group
Myliobatidae	*Mobula* sp.	Pk	No Group
Scaridae	*Scarus fuscocaudalis*	H	Parrotfish
Scaridae	*Calotomus zonarchus*	H	Parrotfish
Scaridae	*Chlorurus japanensis*	H	Parrotfish
Scaridae	*Scarus globiceps*	H	Parrotfish
Scaridae	*Scarus spinus*	H	Parrotfish
Scaridae	*Scarus psittacus*	H	Parrotfish
Scaridae	*Scarus dubius*	H	Parrotfish
Scaridae	*Scarus oviceps*	H	Parrotfish
Scaridae	*Scarus schlegeli*	H	Parrotfish
Scaridae	*Chlorurus spilurus*	H	Parrotfish
Scaridae	*Scarus niger*	H	Parrotfish
Scaridae	*Scarus festivus*	H	Parrotfish
Scaridae	*Scarus frenatus*	H	Parrotfish
Scaridae	*Chlorurus frontalis*	H	Parrotfish
Scaridae	*Scarus dimidiatus*	H	Parrotfish
Scaridae	*Calotomus carolinus*	H	Parrotfish

Family	**Scientific Name**	**Trophic Group**	**Functional Group**
Scaridae	*Scarus forsteni*	H	Parrotfish
Scaridae	*Scarus tricolor*	H	Parrotfish
Scaridae	*Scarus xanthopleura*	H	Parrotfish
Scaridae	*Hipposcarus longiceps*	H	Parrotfish
Scaridae	*Scarus altipinnis*	H	Parrotfish
Scaridae	*Chlorurus perspicillatus*	H	Parrotfish
Scaridae	*Scaridae*	H	Parrotfish
Scaridae	*Scarus rubroviolaceus*	H	Parrotfish
Scaridae	*Chlorurus microrhinos*	H	Parrotfish
Scaridae	*Cetoscarus ocellatus*	H	Parrotfish
Scaridae	*Scarus ghobban*	H	Parrotfish
Scaridae	*Chlorurus* sp.	H	Parrotfish
Scaridae	*Scarus* sp.	H	Parrotfish
Scaridae	*Bolbometopon muricatum*	Cor	Parrotfish
Lutjanidae	*Lutjanus fulvus*	MI	Snappers
Lutjanidae	*Lutjanus kasmira*	MI	Snappers
Lutjanidae	*Lutjanus gibbus*	MI	Snappers
Lutjanidae	*Lutjanus monostigma*	Pisc	Snappers
Lutjanidae	*Macolor macularis*	Pk	Snappers
Lutjanidae	*Aphareus furca*	Pisc	Snappers
Lutjanidae	*Macolor niger*	Pk	Snappers
Lutjanidae	*Macolor* sp.	Pk	Snappers
Lutjanidae	*Lutjanus bohar*	Pisc	Snappers
Lutjanidae	*Lutjanus argentimaculatus*	MI	Snappers
Lutjanidae	*Aprion virescens*	Pisc	Snappers

APPENDIX B: LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT

Table B-1. Protected species found or reasonably believed to be found near or in Hawaii waters

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Seabirds					
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breeding visitor in the NWHI	35 FR 8495, 65 FR 46643, Pyle & Pyle 2009
Northern Fulmar	*Fulmarus glacialis*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Kermadec Petrel	*Pterodroma neglecta*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Herald Petrel	*Pterodroma arminjoniana*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Murphy's Petrel	*Pterodroma ultima*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Mottled Petrel	*Pterodroma inexpectata*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Juan Fernandez Petrel	*Pterodroma externa*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Hawaiian Petrel	*Pterodroma sandwichensis (Pterodroma phaeopygia sandwichensis)*	Endangered	N/A	Breeding visitor in the MHI	32 FR 4001, Pyle & Pyle 2009
White-Necked Petrel	*Pterodroma cervicalis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bonin Petrel	*Pterodroma hypoleuca*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Cook Petrel	*Pterodroma cookii*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Stejneger Petrel	*Pterodroma longirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pycroft Petrel	*Pterodroma pycrofti*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Bulwer's Petrel	*Bulweria bulwerii*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Flesh-Footed Shearwater	*Ardenna carneipes*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Wedge-Tailed Shearwater	*Ardenna pacifica*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Buller's Shearwater	*Ardenna bulleri*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Sooty Shearwater	*Ardenna grisea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Short-Tailed Shearwater	*Ardenna tenuirostris*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Newell's Shearwater	*Puffinus newelli (Puffinus auricularis newelli)*	Threatened	N/A	Breeding visitor	40 FR 44149, Pyle & Pyle 2009
Wilson's Storm-Petrel	*Oceanites oceanicus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Tristram Storm-Petrel	*Oceanodroma tristrami*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White-Tailed Tropicbird	*Phaethon lepturus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Tailed Tropicbird	*Phaethon rubricauda*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Red-Footed Booby	*Sula sula*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Laughing Gull	*Leucophaeus atricilla*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Franklin Gull	*Leucophaeus pipixcan*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Ring-Billed Gull	*Larus delawarensis*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Herring Gull	*Larus argentatus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Slaty-Backed Gull	*Larus schistisagus*	Not Listed	N/A	Winter resident in the NWHI	Pyle & Pyle 2009
Glaucous-Winged Gull	*Larus glaucescens*	Not Listed	N/A	Winter resident	Pyle & Pyle 2009
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Black Noddy	*Anous minutus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Blue-Gray Noddy	*Procelsterna cerulea*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
White Tern	*Gygis alba*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Sooty Tern	*Onychoprion fuscatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Breeding visitor	Pyle & Pyle 2009

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Little Tern	*Sternula albifrons*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Least Tern	*Sternula antillarum*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009
Arctic Tern	*Sterna paradisaea*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
South Polar Skua	*Stercorarius maccormicki*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Pomarine Jaeger	*Stercorarius pomarinus*	Not Listed	N/A	Winter resident in the MHI	Pyle & Pyle 2009
Parasitic Jaeger	*Stercorarius parasiticus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Long-Tailed Jaeger	*Stercorarius longicaudus*	Not Listed	N/A	Migrant	Pyle & Pyle 2009
Sea turtles					
Green Sea Turtle	*Chelonia mydas*	Threatened (Central North Pacific DPS)	N/A	Most common turtle in the Hawaiian Islands, much more common in nearshore state waters (foraging grounds) than offshore federal waters. Most nesting occurs on French Frigate Shoals in the NWHI. Foraging and haul out in the MHI.	43 FR 32800, 81 FR 20057, Balazs et al. 1992, Kolinski et al. 2001
Green Sea Turtle	*Chelonia mydas*	Threatened (East Pacific DPS)	N/A	Nest primarily in Mexico and the Galapagos Islands. Little known about their pelagic range west of 90°W but may range as far as the Marshall Islands. Genetic testing confirmed that they are incidentally taken in the HI DSLL fishery.	43 FR 32800, 81 FR 20057, WPRFMC 2009, Cliffton et al. 1982, Karl & Bowen 1999
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[a]	N/A	Small population foraging around Hawaii and low level nesting on Maui and Hawaii Islands. Occur worldwide in tropical and subtropical waters.	35 FR 8491, NMFS & USFWS 2007, Balazs et al. 1992, Katahira et al. 1994
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[a]	N/A	Not common in Hawai`i. Occur worldwide in tropical, subtropical, and subpolar waters.	35 FR 8491, Eckert et al. 2012
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (North Pacific DPS)	N/A	Rare in Hawai`i. Found worldwide along continental shelves, bays, estuaries, and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Dodd 1990, Balazs 1979

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for the breeding population on the Pacific coast of Mexico, which is listed as endangered)	N/A	Rare in Hawai`i. Occurs worldwide in tropical and warm temperate ocean waters.	43 FR 32800, Pitman 1990, Balacz 1982
Marine mammals					
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Uncommon in Hawaiian waters. Possible separate nearshore and pelagic stocks.	McSweeney et al. 2007, Schorr et al. 2009, Baird et al. 2013
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	Acoustically recorded off of Oahu and Midway Atoll, small number of sightings around Hawai`i. Considered extremely rare, generally occur in winter and summer.	35 FR 18319, Bradford et al. 2013, Northrop et al. 1971, Thompson & Friedl 1982, Stafford et al. 2001
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Common in both inshore shallow waters and offshore deep waters. Evidence for five different populations associated with different island groups and depths.	Baird et al. 2009, Martien et al 2012
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Unknown	Common in Hawaiian Islands.	Bradford et al. 2013
Common Dolphin	*Delphinus delphis*	Not Listed	N/A	Found worldwide in temperate and subtropical seas.	Perrin et al. 2009
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur year round in Hawaiian waters. Possible separate nearshore and pelagic stocks. Nearshore stock found up to 67 km from shore.	McSweeney et al. 2007, Baird et al. 2013
Dall's Porpoise	*Phocoenoides dalli*	Not Listed	Non-strategic	Range across the entire north Pacific Ocean.	Hall 1979
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Non-strategic	Possible resident population. Most common in waters between 500 m and 1,000 m in depth.	Baird et al. 2013

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
False Killer Whale	*Pseudorca crassidens*	Endangered (MHI Insular DPS)	Strategic	Found in waters within a modified 72 km radius around the MHI. Range overlaps with those of two other stocks around Kauai/Niihau. Population declining.	77 FR 70915, Bradford et al. 2015, Baird 2009, Reeves et al. 2009, Oleson et al. 2010
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Two stocks with overlapping ranges around Kauai/Niihau: 1) the Northwestern Hawaiian Islands stock, which includes animals inhabiting waters within the Papahānaumokuākea Marine National Monument and to the east around Kauai, and 2) the Hawaii pelagic stock, which includes false killer whales inhabiting waters greater than 11 km from the main Hawaiian Islands, including adjacent high seas waters. Little known about these stocks.	Bradford et al. 2015
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Infrequent sightings in Hawaii waters. Considered rare in Hawai`i, though may migrate into Hawaiian waters during fall/winter based on acoustic recordings.	35 FR 18319, Hamilton et al. 2009, Thompson & Friedl 1982
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Non-strategic	Distributed worldwide in tropical waters. Rare in Hawaiian waters.	Perrin et al. 2009, Baird et al. 2013, Bradford et al. 2013, Barlow 2006
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered[a]	Strategic	Endemic tropical seal. Occurs throughout the archipelago. MHI population spends some time foraging in federal waters during the day.	41 FR 51611, Baker at al. 2011

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Hawaii DPS)	Strategic	Migrate through the archipelago and breed during the winter. Common during winter months when they are generally found within the 100 m isobath.	35 FR 18319, 81 FR 62259, Childerhouse et al. 2008, Wolman & Jurasz 1976, Herman & Antinoja 1977, Rice & Wolman 1978
Killer Whale	*Orcinus orca*	Not Listed	Non-strategic	Rare in Hawai`i. Prefer colder waters within 800 km of continents.	Mitchell 1975, Baird et al. 2006
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Non-strategic	Found in tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa. Rare in Hawai`i.	Dalebout 2003, Baird et al. 2013
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Non-strategic	Found in tropical and warm-temperate waters worldwide, found primarily in equatorial waters. Uncommon in Hawai`i.	Perryman et al. 1994, Barlow 2006, Bradford et al. 2013
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Non-strategic	Occur seasonally around Hawai`i.	Barlow 2003, Rankin & Barlow 2005
Pantropical Spotted dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Common and abundant throughout the Hawaiian archipelago, including nearshore. Three stocks found in Hawaiian Islands.	Baird et al. 2013
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Small resident population.	McSweeney et al. 2009
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Non-strategic	Rare, found in nearshore waters.	Baird et al. 2013
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Uncommon in Hawai`i.	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Present throughout Hawaii and in offshore waters.	Perrin et al. 2009, Baird et al. 2013, Barlow 2006, Bradford et al. 2013
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Rare in Hawai`i. Generally found in offshore temperate waters.	35 FR 18319, Barlow 2003, Bradford et al. 2013
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Commonly observed around MHI and present around NWHI.	Shallenberger 1981, Bradford et al. 2013, Baird et al. 2013

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region. Sighted off the NWHI and the MHI.	35 FR 18319, Barlow 2006, Lee 1993, Rice 1960, Mobley et al. 2000, Shallenberger 1981
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Occur in shallow protected bays during the day, feed offshore at night. Four stocks associated with island groups.	Karczmarski 2005, Norris & Dohl 1980, Hill et al. 2010, Norris et al. 1994, Andews et al. 2010
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world	Perrin et al. 2009
Elasmobranchs					
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Bonfil et al. 2008, Backus et al. 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead	*Sphyrna lewini*	Endangered (Eastern Pacific DPS)	N/A	Found in coastal areas from southern California to Peru.	Compagno 1984, Baum et al. 2007, Bester 2011
Scalloped hammerhead	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but is rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993

[a] These species have critical habitat designated under the ESA. See Table B-2.

Table B-2. ESA-listed species' critical habitat in the Pacific Ocean[a]

Common Name	Scientific Name	ESA Listing Status	Critical Habitat	References
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	None in the Pacific Ocean.	63 FR 46693
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Approximately 16,910 square miles (43,798 square km) stretching along the California coast from Point Arena to Point Arguello east	77 FR 4170

			of the 3,000 meter depth contour; and 25,004 square miles (64,760 square km) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.	
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered	Ten areas in the Northwestern Hawaiian Islands (NWHI) and six in the main Hawaiian Islands (MHI). These areas contain one or a combination of habitat types: Preferred pupping and nursing areas, significant haul-out areas, and/or marine foraging areas, that will support conservation for the species.	53 FR 18988, 51 FR 16047, 80 FR 50925
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Two specific areas are designated, one in the Gulf of Alaska and another in the Bering Sea, comprising a total of approximately 95,200 square kilometers (36,750 square miles) of marine habitat.	73 FR 19000, 71 FR 38277

[a] For maps of critical habitat, see https://www.fisheries.noaa.gov/national/endangered-species-conservation/critical-habitat.

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