ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT:

HAWAII ARCHIPELAGO FISHERY ECOSYSTEM PLAN 2017

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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT for the HAWAII ARCHIPELAGO FISHERY ECOSYSTEM 2017 was drafted by the Fishery Ecosystem Plan Team. This is a collaborative effort primarily between the Western Pacific Regional Fishery Management Council, NMFS-Pacific Island Fisheries Science Center, Pacific Islands Regional Office, and the Division of Aquatic Resources (HI) Department of Marine and Wildlife Resources (AS), Division of Aquatic and Wildlife Resources (Guam), and Division of Fish and Wildlife (CNMI).

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.

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EXECUTIVE SUMMARY

As part of its five-year fishery ecosystem plan (FEP) review, the Council identified the annual reports as a priority for improvement. The former annual reports have been revised to meet National Standard regulatory requirements for the Stock Assessment and Fishery Evaluation (SAFE) reports. The purpose of the report 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 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 section of this report presents descriptions of Hawaiian commercial fisheries including Deep 7 bottomfish, non-Deep 7 bottomfish, coral reef, crustacean, and mollusk and limu management unit species (MUS). The data collection systems for each fishery are 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 for historical fishing parameters, top species catch by gear, and total catch values by gear are also provided. For 2017 catch in Hawaii, none of the evaluated MUS exceeded their associated annual catch limits (ACL), allowable biological catch (ABC) values, or overfishing limits (OFL). Note that ACLs were not specified for Kona crab, non-Deep 7 bottomfish, or coral reef ecosystem management unit species because the National Marine Fisheries Service (NMFS) had recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these MUS. Recent average catch for the Main Hawaiian Island Deep 7 bottomfish stock complex (266,550 lbs.) accounted for 87.1% of its prescribed ACL (306,000 lbs.).

In 2017, the Main Hawaiian Island Deep 7 bottomfish fishery was characterized by decreasing trends in fishing effort and participation relative to measured averages. Though the number of fish caught and the pounds landed also decreased, effort and participation were lower to the extent that CPUE for the fishery increased relative to short- and long-term averages. The Deep 7 catch was mostly from deep sea handline. The non-Deep 7 bottomfish fishery was dominated by uku (*Aprion virescens*) with a smaller contribution from white ulua (*Caranx ignobilis*). Fishery participation and effort were relatively consistent with short-term values and showed a slight increase in comparison with 20-year averages. The total number and pounds caught of non-Deep 7 bottomfish caught were both up overall in 2017 from previous years. Non-Deep 7 species were mostly landed using the deep-sea handline, inshore-handline, and troll method. The deep-sea handline method had interannual increases in participation, effort, catch, and CPUE. The inshore handline showed the same pattern of increasing participation, effort, and catch, though associated CPUE was slightly less.

The coral reef ecosystem management unit species (CREMUS) finfish fishery, in general, exhibited a decline in fishing participation, effort, and catch from 2016 and decadal average values. The CREMUS fishery was dominated by inshore handline landing coastal pelagic species, followed by purse seine, lay gill net, and seine net landing other schooling and coastal pelagic species. Inshore handline had relatively low values for effort, participation, catch, and CPUE in 2017, and purse seine also showed a general decrease across these parameters. Conversely, lay gill net had an increase in catch and CPUE relative to short- and long-term average values, while effort and participation were slightly lower. Seine net showed an increase in effort from 2016; though catch and CPUE were on par with short-term averages, they were much less than the values noted for long-term averages. The last notable gear used was the spear that showed a general decline in 2017 for all monitored fishery parameters.

In 2017, the crustacean fishery showed an overall decline. Considering the crustacean MUS evaluated, participation and catch values in the fishery for deepwater shrimp (*Heterocarpus laevigatus*) were not disclosed due to data confidentiality despite having shown an increase in catch and CPUE last year. Kona crab and lobsters fishery statistics were all down in 2017.

Monitoring for invertebrate fisheries for mollusks and limu was generally focused on hand harvest, spear, and inshore handline. Hand picking for invertebrates showed a general decline for opihi and opihi'alina alongside an increase for lime kohu. Spearing for day octopus had an increase in effort, participation, catch, and CPUE from last year, though CPUE was on par with short- and long-term averages. Other octopus landed using the inshore handline also showed an increase in CPUE despite the overall decline in effort, participation, and catch values.

Ecosystem considerations were added to the annual SAFE report following the Council's review of its fishery ecosystem plans and revised management objectives. Fishery independent ecosystem survey data, human dimensions, protected species, climate and oceanographic, essential fish habitat, and marine planning information are included in the ecosystem considerations section.

Fishery independent ecosystem survey data was acquired through visual surveys conducted in Main Hawaiian Islands (MHI), Northwest Hawaiian Islands (NWHI), American Samoa, Pacific Remote Island Area, Commonwealth of Northern Mariana Islands, and Guam. This report illustrates the mean fish biomass for the reef areas within these locations. Additionally, the mean reef fish biomass and mean size of fishes (>10 cm) for the MHI and NWHI are presented by sampling year and reef area. Finally, the reef fish population estimates for each study site within MHI and NWHI are provided for hardbottom habitat (0-30 m).

This year for the Main Hawaiian Islands, a section was added showing life history parameters for a handful of species of both coral reef fish and bottomfish. 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

The socioeconomic section begins with an overview of the socioeconomic context for the region, provides a summary of relevant studies and data for Hawaii, summarizes relevant studies and data for each fishery within the Main Hawaiian Islands, and displays relevant socioeconomic data trends including commercial pounds sold, revenues, and prices. Considering the Hawaiian bottomfish fishery, the most recently calculated average cost of a bottomfish trip was approximately $253. For the coral reef fishery in the area, the average cost of a spearfishing trip was notably cheaper than bottomfishing in the Main Hawaiian Islands at $159. There were no new data reported for neither the crustacean nor the precious coral fisheries in the Main Hawaiian Islands.

The protected species section of this report summarizes information and monitors protected species interactions in fisheries managed under the Hawaii FEP. These fisheries generally have limited impacts to protected species, and currently do not have federal observer coverage. Consequently, this report tracks fishing effort and other characteristics to detect potential changes to the level of impacts to protected species. Fishery performance data contained 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 to indicate that impacts to protected species have changed in recent years.

The climate change section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Western Pacific Regional Fishery Management Council has responsibility. 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 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, as well as provide historical context and recognize patterns and trends. The atmospheric concentration of carbon dioxide (CO_2) trend has been increasing exponentially with the time series maximum at 406.53 ppm in 2017. The oceanic pH at Station Aloha in Hawaii has shown a significant linear decrease of -0.0386 pH units, or roughly a 9% increase in acidity ([H+]) since 1989. The year 2017 had relatively low temperature anomalies, with values not surpassing two degree heating weeks in area surrounding the Main Hawaiian Islands. The East Pacific hurricane season saw 18 named storms in 2017, nine of which were hurricanes and four major. The north central Pacific, conversely, had no storms over the course of 2017. This year, the climate change section was updated with information on storm-force winds as well as an additional indicator for precipitation.

The essential fish habitat (EFH) review section of this report is required by the Hawaii Archipelago FEP and National Standard 2 guidelines, and 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 Appendix C of the 2017 annual SAFE report, a literature review of the life history and habitat requirements for each life stage of four reef-associated crustaceans species regularly landed in U.S. Western Pacific commercial fisheries is presented. This review includes information on two species of spiny lobster, (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*). The most up to date information on species distribution, fisheries status, and life history are summarized. The EFH section is also meant to address any Council directives toward its Plan Team; however, there were no Plan Team directives in 2017.

The marine planning section of this report tracks 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. In the Hawaii Archipelago, alternative energy development and military activities are those with the highest potential fisheries impact.

The Bureau of Ocean Energy Management received four nominations of commercial interest for its Call Areas northwest and south of Oahu, all of which are in the area identification and environmental assessment stage of the leasing process. The Department of Defense is released a draft environmental impact statement regarding activities entitled "Hawaii-Southern California Training and Testing" in October 2017; these activities will likely impact fishing access and fish habitat.

The data integration chapter of this report is still under development. The Council hosted a Data Integration Workshop in late 2016 with a goal of identifying policy-relevant fishery ecosystem relationships. The archipelagic data integration chapter currently explores the potential association between fishery parameters and precipitation, primary productivity, and temperature-derived variables. A contractor has recently completed these analyses, and initial results of exploratory analyses are included for the first time in 2017. The commercial coral reef fisheries of the Main Hawaiian Islands generally showed weak associations with the environmental parameters evaluated. No connection was discovered between the sum of the coral reef fisheries in the region with sea surface temperature, though the weke (i.e. goatfish of the family Mullidae) taxa group had a positively-significant statistical relationship with the variable. No general associations were discovered between precipitation and akule or opelu. Lastly, the relationship between the sum of the commercial reef fisheries in the Main Hawaiian Islands and the concentration of fluorometric chlorophyll-*a* integrated over the top 200 meters of the water column was determined to be statistically significant in a negative fashion. In line with these results, the ta'ape taxa group showed the strongest significant relationship with the same environmental variable, also negative. A non-metric multidimensional scaling analysis showed that, while the evaluation was not able to identify any significant levels of association between expanded creel catch data and a swath of environmental parameters, the first axis, responsible for explaining 94% of the variance, showed the strongest relationships with salinity (negative) and pH (positive). In continuing forward with associated analyses and presentation of results for the data integration chapter, the Plan Team suggested several improvements to implement in the coming year: standardizing and correcting values in CPUE time series, incorporating longer stretches of phase lag, completing comparisons on the species-level and by dominant gear types, incorporating local knowledge on shifts in fishing dynamics over the course of the time series, and utilizing the exact environmental data sets presented in the ecosystem consideration chapter of the annual report. Implementation of these suggestions will allow for the preparation of a more finalized version of the data integration chapter in the coming year.

The 2018 Archipelagic Plan Team had no recommendations specific to the 2017 Hawaii FEP Annual SAFE Report.

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ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
ABC	Acceptable Biological Catch
ACE	Accumulated Cyclone Energy
ACL	Annual Catch Limits
ACT	Annual Catch Target
AM	Accountability Measures
AVHRR	Advanced Very High Resolution Radiometer
BAC-MSY	Biomass Augmented Catch MSY
B_{FLAG}	warning reference point for biomass
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BOEM	Bureau of Ocean Energy Management
BSIA	Best Scientific Information Available
CFR	Code of Federal Regulations
CMLS	Commercial Marine License System
CMS	Coastal and Marine Spatial
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CPUE	Catch per Unit Effort
CRED	Coral Reef Ecosystem Division
CREMUS	Coral Reef Ecosystem Management Unit Species
DLNR-DAR	Dept. of Land and Natural Resources – Div. of Aquatic Resources
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EKE	Eddy Kinetic Energy
ENSO	El Niño Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FRS	Fishing Report System
GAC	Global Area Coverage
GFS	Global Forecast System
HAPC	Habitat Area of Particular Concern
HDAR	Hawaii Division of Aquatic Resources
IBTrACS	International Best Track Archive for Climate Stewardship
LOF	List of Fisheries
LVPA	Large Vessel Prohibited Area
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Island
MMA	Marine Managed Area

MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
MPCC	Marine Planning and Climate Change
MPCCC	Council's MPCC Committee
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
MUS	Management Unit Species
NCADAC	Nat'l Climate Assessment & Development Advisory Committee
NCDC	National Climatic Data Center
NEPA	National Environmental and Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NMFS	National Marine Fisheries Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWHI	Northwestern Hawaiian Islands
OFL	Overfishing Limits
OFR	Online Fishing Report
ONI	Ocean Niño Index
OR&R	Office of Response and Restoration
OY	Optimum Yield
PacIOOS	Pacific Integrated Ocean Observing System
PCMUS	Precious Coral Management Unit Species
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PI	Pacific Islands
PIBHMC	Pacific Island Benthic Habitat Mapping Center
PIFSC	Pacific Island Fisheries Science Center
PIRCA	Pacific Islands Regional Climate Assessment
PIRO	NOAA NMFS Pacific Islands Regional Office
PMUS	Pelagic Management Unit Species
POES	Polar Operational Environmental Satellite
PRIA	Pacific Remote Island Areas
RAMP	Reef Assessment and Monitoring Program
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SBRM	Standardized Bycatch Reporting Methodologies
SDC	Status Determination Criteria
SEEM	Social, Economic, Ecological, Management uncertainties
SPC	Stationary Point Count
SST	Sea Surface Temperature
TAC	Total Allowable Catch
USACE	United States Army Corps of Engineers
WPacFIN	Western Pacific Fishery Information Network
WPRFMC	Western Pacific Regional Fishery Management Council
WPSAR	Western Pacific Stock Assessment Review

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1 FISHERY PERFORMANCE

1.1 DEEP 7 BMUS

1.1.1 Fishery Descriptions

The State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources 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 State collects the fishery information, the NMFS analyzes this information, and the Council, working with the State, proposes the management scheme. Lastly, the NMFS implements the scheme into federal regulations before the State adopts state regulations. These three 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 complex of species occurs in both State and Federal waters. The information in this report is largely based on State-collected data.

1.1.2 Data Collection Systems

The collection of commercial main Hawaiian Islands 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) at www.dlnr.ehawaii.gov/cmls-fr. Since the federal management of the Deep 7 bottomfish fishery began in 2007, bottomfish landings have been collected on three types of fishing reports. Initially, bottomfishers 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, and bottomfish fishers were required to submit the trip report within five days of the trip end date. DLNR-DAR implemented the OFR online website in February 2010.

Paper fishing reports received through mail by DLNR-DAR are initially processed by an office assistant that date stamps the report, scans the report image, and enters the report header as index information into an archival database application to store them as database files. The report header index information is downloaded in a batch text file via FTP at 12:00 AM for transmission to the web portal vendor that maintains the Commercial Marine Licensing System (CMLS). This information updates the fisher's license report log in the CMLS to credit submission of the fishing report. The web portal vendor also exports a batch text file extract of the updated license profile and report log data file via FTP on a daily basis at 2:00 AM for transmission to DLNR-DAR. The office assistant checks reports for missing information, sorts by fishery form type (e.g. Deep 7 or Monthly Fishing Report), and distributes it to the appropriate database assistant by the next business day. Database assistants and the data monitoring associate enter the Deep-sea Handline Fishing Trip Report into the DLNR-DAR Fishing Report System (FRS) database, and enter the other report types through the Online Fishing Reporting System (OFR) within two business days.

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 DLNR-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 WPacFIN daily where data trends are created and reported weekly to Deep 7 fishery managers and stake holders. A bottomfish newsletter is published for bottomfishers and fish dealers on a quarterly basis.

1.1.2.1 Historical Summary

Table 1. Annual fishing parameters for the 2017 fishing year in the MHI Deep 7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages.

Fishery	Parameters	2017 Values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
BMUS Deep 7	No. License	339	↓ 20.4%	↓ 19.9%
	Trips	2,327	↓ 19.2%	↓ 23.8%
	No. Caught	65,886	↓ 4.29%	↓ 2.47%
	Lbs. Caught	235,731	↓ 5.11%	↓ 5.24%

1.1.2.2 Species Summary

Table 2. Annual fishing parameters for the 2017 fishing year in the MHI Deep 7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages.

Methods	Fishery indicators	2017 values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Deep-Sea Handline	Opakapaka	132,329 lbs.	↑ 8.40%	↑ 9.01%
	Onaga	45,786 lbs.	↓ 30.6%	↓ 32.5%
	Ehu	23,948 lbs.	↓ 8.05%	↓ 0.55%
	Hapuupuu	7,675 lbs.	↓ 12.5%	↓ 23.3%
	No. Lic.	323	↓ 20.1%	↓ 19.7%
	No. Trips	2,180	↓ 21.2%	↓ 26.3%
	Lbs. Caught	229,469 lbs.	↓ 7.08%	↓ 7.09%
	CPUE	105.3 lbs./trip	↑ 17.0%	↑ 23.8%
Inshore Handline	Opakapaka Ehu Lehi Onaga	Insufficient data to report trends		
	No. Lic.	4	↓ 60.0%	↓ 63.6%

	No. Trips	4	↓ 78.9%	↓ 80.0%
	Lbs. Caught	15 lbs.	↓ 97.7%	↓ 97.2%
	CPUE	3.75 lbs./trip	↓ 86.6%	↓ 82.1%
Palu-ahi	Opakapaka	3,168 lbs.	↑ 243%	↑ 442%
	Ehu	Insufficient data to report trends		
	Lehi	986 lbs.	↑ 1.75%	↑ 45.0%
	Hapuupuu	Insufficient data to report trends		
	No. Lic.	23	0%	↑ 21.1%
	No. Trips	121	↑ 47.6%	↑ 102%
	Lbs. Caught	4,484 lbs.	↑ 116%	↑ 233%
	CPUE	37.1 lbs./trip	↑ 54.4%	↑ 95.1%

1.1.3 Time Series Statistics

1.1.3.1 Commercial Fishing Parameters

The time series format for the Deep 7 bottomfish fishery begins with an arrangement 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 it was issued. During that period, each fisher received a different CML number, reducing duplicate licensee counts through June 1993. The State issued and renewed permanent CML numbers effective July 1993. 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 and ending in August 2015. 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, this artisan fishery is dominated by highliners with large landings. Beginning in Fiscal Year 1966, less than 100 fishers made just over 1,000 trips but attained the highest CPUE at 178 pounds per trip. With the expansion of the small vessel fleet during the 1970s and 1980s, effort and landings increased until peaking in the late-80s at 559,293 lbs. in 6,253 trips. In June 1993, the State established bottomfish regulations including: bottomfish restricted fishing areas, vessel registration identification, and non-commercial bag limits. Fishing effort and landings further declined as a result. Since the implementation of federal Deep 7 bottomfish management, landings have been under the jurisdiction of the former total annual catch (TAC) and now annual catch limit (ACL) fishing quotas.

Table 3. Time series of commercial fishermen reports for Deep 7 BMUS fishery (1966-2017). Historical record reported by Fiscal Year from 1966-1993 and by Fishing Year from 1994-2017. Data from July and August 1993 were omitted to allow for this change.

Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1966	92	1,055	413	11,018	181,629
1967	110	1,469	550	16,005	231,315

Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1968	121	1,193	524	12,906	194,851
1969	132	1,216	532	11,409	177,381
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	2,161	938	23,976	225,561
1975	247	2,094	903	24,052	221,385
1976	303	2,265	995	23,896	250,270
1977	338	2,722	1,173	26,872	274,298
1978	434	2,658	1,540	41,381	307,672
1979	447	2,255	1,517	32,312	273,846
1980	461	2,853	1,435	35,096	244,219
1981	486	3,769	1,636	45,085	308,296
1982	451	3,917	1,634	46,873	329,436
1983	539	4,875	1,890	61,857	409,241
1984	553	4,462	1,799	55,532	340,790
1985	551	5,752	2,043	88,679	484,042
1986	605	5,748	2,256	99,886	509,121
1987	581	5,572	2,178	132,498	579,170
1988	550	6,033	2,122	136,728	566,724
1989	564	6,253	2,231	117,599	559,293
1990	531	5,249	1,944	90,353	455,802
1991	499	4,223	1,773	68,411	334,673
1992	488	4,508	1,846	85,693	371,245
1993	450	3,550	1,497	63,668	265,287
1993	121	374	168	7,356	28,826
1994	518	3,886	1,698	84,875	318,461
1995	525	3,921	1,706	78,159	320,940
1996	519	3,999	1,755	84,096	295,881
1997	500	4,189	1,762	83,893	307,615
1998	520	4,119	1,733	83,781	290,083
1999	430	3,007	1,428	56,682	214,004
2000	497	3,929	1,697	84,064	311,611
2001	457	3,572	1,550	71,433	265,755
2002	388	2,856	1,334	54,520	209,351
2003	364	2,936	1,248	62,891	246,814
2004	331	2,649	1,138	57,386	208,743
2005	351	2,702	1,198	61,410	241,660
2006	352	2,266	1,051	45,427	189,550

Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
2007	356	2,548	1,144	49,953	204,792
2008	353	2,345	1,023	49,423	196,889
2009	476	3,266	1,473	66,836	258,335
2010	460	2,787	1,224	56,645	207,978
2011	472	3,423	1,408	74,412	273,053
2012	479	3,079	1,520	67,956	226,704
2013	458	2,977	1,497	68,445	239,063
2014	423	3,172	1,492	90,291	311,179
2015	410	2,886	1,413	90,793	307,075
2016	372	2,344	1,194	76,831	277,454
2017	339	2,327	1,152	65,886	235,731
10-year avg.	**426**	**2,879**	**1,338**	**68,839**	**248,431**
20-year avg.	**423**	**3,052**	**1,376**	**67,554**	**248,757**

1.1.4 Top Four Species per Gear Type

1.1.4.1 Deep-sea Handline

The heavy tackle, deep-sea handline gear is the dominant method for this fishery. The opakapaka and onaga are the primary target species, with the latter requiring much more fishing skill. In recent years, bottomfishers have remarked that opakapaka is the preferred target due to less fishing area and because it is easier to land for what is now a one-day fishery.

Table 4. HDAR MHI Fiscal Annual Deep 7 catch (lbs. caught) summary (1966-2017) by species and top gear: Deep-sea handline. Historical record reported by Fiscal Year from 1966-1993 and by Fishing Year from 1994-2017. Data from July and August 1993 were omitted to allow for this change.

Year	Opakapaka		Onaga		Ehu		Hapuupuu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	76	70,651	34	63,965	47	17,587	49	11,644
1967	96	120,888	43	68,442	62	18,350	60	10,624
1968	97	83,983	62	69,504	68	19,864	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	113	21,136	108	23,078
1976	224	101,618	118	78,684	105	21,621	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	147,342	161	29,889	183	15,836	182	16,984
1981	386	193,944	153	42,659	207	20,754	188	16,056
1982	370	173,803	177	65,235	233	24,088	189	20,854
1983	422	226,589	240	71,687	277	27,450	209	31,733
1984	394	153,138	239	84,602	281	35,214	207	26,286
1985	437	196,016	296	162,305	308	40,325	250	30,960
1986	475	171,581	343	194,172	368	59,768	241	23,593
1987	454	254,234	287	173,638	320	45,258	175	27,703
1988	445	299,861	272	156,077	296	41,010	194	10,039
1989	436	306,607	302	142,829	318	37,110	184	13,288
1990	419	209,597	307	141,419	312	37,326	176	13,488
1991	385	138,285	276	104,562	301	32,397	169	17,217
1992	375	174,138	253	95,363	308	33,331	165	17,915
1993	346	138,439	194	52,703	256	25,588	167	15,721
1993	85	14,511	51	5,707	61	3,087	35	2,120
1994	393	176,118	241	71,989	287	22,658	190	11,610
1995	427	179,674	236	65,906	289	26,001	230	15,564
1996	417	148,425	245	68,198	279	31,371	223	12,017
1997	380	160,062	218	61,209	266	28,676	216	15,796
1998	386	146,576	250	68,984	299	25,402	215	12,458
1999	325	101,755	198	60,605	233	19,747	179	9,908
2000	386	166,796	251	72,599	283	27,600	209	13,569
2001	340	127,076	253	64,661	273	25,856	203	15,845
2002	288	100,796	194	59,867	218	17,149	165	8,676
2003	256	127,191	190	69,473	214	15,768	142	9,442
2004	233	87,126	185	76,754	193	20,557	131	8,384
2005	249	102,641	202	87,588	208	21,948	131	10,548
2006	245	73,282	202	74,745	206	18,327	122	7,635
2007	270	82,512	202	80,629	223	17,566	118	6,155
2008	271	94,145	197	55,680	210	17,910	133	6,729
2009	361	132,724	245	59,827	295	24,649	168	7,808
2010	324	102,000	251	56,166	296	23,718	165	8,022
2011	367	146,934	258	67,375	304	24,124	175	8,002
2012	341	109,265	261	55,524	321	27,276	157	9,737
2013	326	98,600	246	68,383	306	31,332	156	10,342
2014	324	162,369	233	75,213	275	30,408	161	10,667
2015	308	150,657	227	78,044	269	33,058	138	9,930
2016	280	136,357	201	73,792	232	32,050	120	10,010
2017	263	131,329	172	45,786	222	23,948	127	7,675

10-year avg.	**318**	**121,154**	**232**	**65,949**	**273**	**26,045**	**149**	**8,774**
20-year avg.	**313**	**120,474**	**223**	**67,811**	**256**	**24,080**	**160**	**10,005**

1.1.4.2 Inshore Handline

The inshore handline gear is supposed to be a lighter tackle than the deep-sea handline. The ehu and onaga landings were probably made with the heavier tackle gear, but were reported by fishers as inshore handline. For these cases in recent years, fishers were contacted to verify the gear reported. The fishing report was not amended if the fisher did not respond. The opakapaka and lehi landings were likely fished in shallow-water habitat.

Table 5. HDAR MHI fiscal annual Deep 7 catch (lbs. caught) summary (1966-2017) by species and second gear: Inshore handline. Historical record reported by Fiscal Year from 1966-1993 and by Fishing Year from 1994-2017. Data from July and August 1993 were omitted to allow for this change.

Year	Opakapaka		Ehu		Lehi		Onaga	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	4	500	4	55	n.d.	n.d.	n.d.	n.d.
1967	n.d.	n.d.	NULL	NULL	n.d.	n.d.	NULL	NULL
1968	NULL	NULL	n.d.	n.d.	NULL	NULL	NULL	NULL
1969	n.d.	n.d.	4	80	NULL	NULL	n.d.	n.d.
1970	n.d.	n.d.	NULL	NULL	4	129	NULL	NULL
1971	4	56	5	26	n.d.	n.d.	6	57
1972	n.d.	n.d.	3	26	n.d.	n.d.	n.d.	n.d.
1973	n.d.	n.d.	3	37	3	32	n.d.	n.d.
1974	n.d.	n.d.	NULL	NULL	n.d.	n.d.	NULL	NULL
1975	12	1318	3	54	6	327	n.d.	n.d.
1976	21	975	9	398	10	387	11	857
1977	40	2552	27	1024	12	473	13	1572
1978	43	1735	28	415	36	943	5	84
1979	100	4644	60	1451	53	1934	19	1406
1980	13	113	9	40	21	712	3	14
1981	18	531	9	39	14	336	5	26
1982	15	111	16	129	19	296	6	84
1983	30	228	24	235	22	360	11	283
1984	16	668	16	154	29	274	14	883
1985	NULL	NULL	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1986	8	267	4	36	5	29	n.d.	n.d.
1987	13	647	n.d.	n.d.	3	16	NULL	NULL
1988	4	53	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Year	Opakapaka		Ehu		Lehi		Onaga	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1989	6	291	5	33	NULL	NULL	n.d.	n.d.
1990	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
1991	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1992	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1993	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1993	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1994	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1995	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1996	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1997	3	22	n.d.	n.d.	4	29	n.d.	n.d.
1998	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	NULL	NULL
1999	NULL	NULL	NULL	NULL	n.d.	n.d.	NULL	NULL
2000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2001	6	80	3	74	NULL	NULL	NULL	NULL
2002	5	51	n.d.	n.d.	NULL	NULL	n.d.	n.d.
2003	7	211	6	191	n.d.	n.d.	n.d.	n.d.
2004	15	824	6	51	3	7	5	90
2005	9	772	5	246	7	68	3	200
2006	6	539	3	21	NULL	NULL	n.d.	n.d.
2007	9	1074	3	430	4	88	n.d.	n.d.
2008	5	268	n.d.	n.d.	3	24	n.d.	n.d.
2009	15	733	4	78	3	111	3	40
2010	14	250	8	172	3	33	4	63
2011	7	242	3	13	n.d.	n.d.	NULL	NULL
2012	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
2013	3	12	NULL	NULL	n.d.	n.d.	NULL	NULL
2014	NULL	NULL	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2016	n.d.	n.d.	NULL	NULL	n.d.	n.d.	NULL	NULL
2017	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
10 -year avg.	**7**	**335**	**3**	**162**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
20- year avg.	**7**	**308**	**3**	**108**	**n.d.**	**n.d.**	**n.d.**	**n.d.**

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

1.1.4.3 Palu Ahi

The primary use of palu ahi gear as defined by the State database is as a form of tuna handline. It is a handline gear primarily used during the day with a drop stone or weight and chum. The target species is usually pelagic, including yellowfin and bigeye tuna. The Deep 7 bottomfish landings from palu ahi are common bycatch for Big Island fishers. Some of the landings may have been taken by bottomfishers who used deep-sea handline tackle but reported it as palu ahi because of the gear definition, which involves weights and chum on a handline. For these cases in recent years, fishers were contacted to verify their reported gear. The fishing report was not amended if the fisher did not respond.

Table 6. HDAR MHI fiscal annual Deep 7 catch (lbs. caught) summary (1966-2017) by species and third gear: palu ahi. Historical record reported by Fiscal Year from 1966-1993 and by Fishing Year from 1994-2017. Data from July and August 1993 were omitted to allow for this change.

Year	Opakapaka		Ehu		Lehi		Hapuupuu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1983	n.d.	n.d.	NULL	NULL	3	50	NULL	NULL
1984	3	629	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1985	NULL	NULL	NULL	NULL	n.d.	n.d.	NULL	NULL
1986	10	275	n.d.	n.d.	9	1087	NULL	NULL
1987	6	112	n.d.	n.d.	9	331	NULL	NULL
1988	n.d.	n.d.	n.d.	n.d.	9	165	n.d.	n.d.
1989	3	110	NULL	NULL	4	91	NULL	NULL
1990	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1991	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1992	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1993	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1993	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1994	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1995	n.d.	n.d.	NULL	NULL	6	92	NULL	NULL
1996	4	15	NULL	NULL	12	228	NULL	NULL
1997	3	64	n.d.	n.d.	14	226	NULL	NULL
1998	n.d.	n.d.	NULL	NULL	11	291	NULL	NULL
1999	5	86	NULL	NULL	13	410	NULL	NULL
2000	8	133	NULL	NULL	11	302	NULL	NULL
2001	4	30	NULL	NULL	4	34	NULL	NULL
2002	NULL	NULL	n.d.	n.d.	4	135	n.d.	n.d.
2003	10	298	n.d.	n.d.	12	450	n.d.	n.d.
2004	13	436	n.d.	n.d.	15	717	3	68
2005	11	134	n.d.	n.d.	16	551	n.d.	n.d.
2006	8	680	NULL	NULL	18	782	NULL	NULL
2007	9	340	n.d.	n.d.	12	539	NULL	NULL
2008	12	1754	3	8	16	1238	3	39
2009	8	1731	5	97	26	1613	n.d.	n.d.
2010	14	272	4	73	20	683	n.d.	n.d.

Year	Opakapaka		Ehu		Lehi		Hapuupuu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
2011	4	168	n.d.	n.d.	9	218	n.d.	n.d.
2012	18	400	n.d.	n.d.	18	1029	n.d.	n.d.
2013	21	1174	n.d.	n.d.	21	1505	n.d.	n.d.
2014	24	1217	4	24	25	1322	NULL	NULL
2015	16	1491	n.d.	n.d.	19	938	n.d.	n.d.
2016	14	698	n.d.	n.d.	11	598	n.d.	n.d.
2017	17	3168	n.d.	n.d.	19	986	4	122
10-year avg.`	**14**	**923**	**3**	**43**	**18**	**969**	**n.d.**	**n.d.**
20 - year avg.	**11**	**584**	**n.d.**	**n.d.**	**15**	**680**	**n.d.**	**n.d.**

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

1.1.5 Catch Parameters by Gear

The CPUE (lbs. per trip) for deep-sea handline peaked at the beginning of the time series, and has leveled off starting in the early 1990s and through 2012. The relatively stable CPUE ranging between 71 and 92 lbs. per trip is attributed to state and federal regulations that removed fishing areas, created an interim closed season, and enforced quotas on landings. However, CPUE has been trending up since 2014, and in 2017 it was approximately 105 lbs. per trip. Fishers have been making fewer trips, but the landings have been larger because the size and/or weight of the Deep 7 bottomfish catch has been increasing.

Table 7. HDAR MHI fiscal annual Deep 7 CPUE by dominant fishing methods (1966-2016). Historical record reported by Fiscal Year from 1966-1993 and by Fishing Year from 1994-2016. July and August 1993 omitted to allow for this change.

Year	Deep-sea handline				Inshore handline				Palu ahi			
	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE
1966	86	1,012	180,165	178.03	10	16	711	44.44	NULL	NULL	NULL	0
1967	107	1,449	231,014	159.43	4	5	45	9	NULL	NULL	NULL	0
1968	118	1,164	194,494	167.09	n.d.	n.d.	n.d.	4.5	NULL	NULL	NULL	0
1969	128	1,175	176,874	150.53	8	14	234	16.71	NULL	NULL	NULL	0
1970	135	1,118	157,853	141.19	5	6	161	26.83	NULL	NULL	NULL	0
1971	163	1,219	134,916	110.68	14	24	185	7.71	NULL	NULL	NULL	0
1972	214	1,896	227,744	120.12	15	22	182	8.27	NULL	NULL	NULL	0
1973	201	1,537	168,976	109.94	13	16	117	7.31	NULL	NULL	NULL	0

1974	258	2,126	225,181	105.92	4	6	61	10.17	NULL	NULL	NULL	0
1975	238	2,038	219,094	107.5	21	39	1,864	47.79	NULL	NULL	NULL	0
1976	270	2,028	241,655	119.15	50	103	3,134	30.43	NULL	NULL	NULL	0
1977	290	2,263	255,125	112.74	61	195	7,428	38.09	NULL	NULL	NULL	0
1978	392	2,365	297,167	125.65	103	209	3,866	18.5	NULL	NULL	NULL	0
1979	379	1,901	259,999	136.77	171	327	11,685	35.73	NULL	NULL	NULL	0
1980	412	2,591	235,253	90.8	49	92	1,038	11.28	NULL	NULL	NULL	0
1981	456	3,458	301,716	87.25	48	79	1,114	14.1	NULL	NULL	NULL	0
1982	429	3,688	322,688	87.49	58	103	742	7.2	n.d.	n.d.	n.d.	n.d.
1983	501	4,571	401,606	87.86	90	166	1,482	8.93	3	8	64	n.d.
1984	503	4,157	330,294	79.39	82	148	2,535	17.13	5	22	930	42.27
1985	533	5,623	481,308	85.6	10	13	1,024	78.77	n.d.	n.d.	n.d.	n.d.
1986	582	5,563	503,729	90.55	27	42	790	18.81	12	63	1,403	22.27
1987	562	5,412	569,395	105.21	21	39	887	22.74	13	35	484	13.83
1988	534	5,955	564,910	94.86	11	15	141	9.4	9	17	262	15.41
1989	536	6,155	556,924	90.48	20	27	629	23.3	5	12	201	16.75
1990	526	5,230	454,948	86.99	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	0
1991	492	4,205	334,546	79.56	4	4	55	13.75	NULL	NULL	NULL	0
1992	483	4,485	371,088	82.74	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	0
1993	445	3,537	265,195	74.97	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	0
1993	120	372	28,773	77.35			NULL	0	NULL	NULL	NULL	0
1994	511	3,864	318,157	82.34	6	7	64	9.14	NULL	NULL	NULL	0
1995	516	3,897	320,634	82.28	n.d.	n.d.	n.d.	n.d.	6	6	105	17.5
1996	507	3,952	295,248	74.71	5	6	28	4.67	13	21	243	11.57
1997	484	4,129	306,177	74.15	13	16	128	8	16	23	301	13.09
1998	506	4,056	288,890	71.23	7	7	69	9.86	11	30	301	10.03
1999	415	2,920	213,039	72.96	4	4	38	9.5	14	48	496	10.33
2000	492	3,885	311,032	80.06	6	8	59	7.38	13	30	435	14.5
2001	447	3,536	265,437	75.07	9	19	178	9.37	6	9	79	8.78
2002	381	2,826	208,840	73.9	9	14	93	6.64	5	14	199	14.21
2003	345	2,844	244,718	86.03	14	26	543	20.88	16	49	850	17.35
2004	301	2,530	206,293	81.52	19	40	1,117	27.93	21	72	1,271	17.65
2005	319	2,596	239,409	92.19	21	50	1,389	27.78	22	49	803	16.39
2006	323	2,155	186,274	87.87	11	27	673	24.93	19	61	1,464	24
2007	334	2,433	201,381	82.78	14	46	2,291	49.8	16	56	902	16.11
2008	331	2,241	192,029	85.72	8	15	1,494	99.6	20	78	3,119	39.99
2009	448	3,117	252,861	81.12	18	29	1,078	37.17	31	105	3,943	37.55
2010	421	2,660	205,699	77.26	25	41	616	15.02	28	67	1,352	20.18
2011	449	3,330	270,282	81.09	9	18	284	15.78	11	33	542	16.38
2012	464	2,979	224,953	75.89	3	3	19	6.33	23	90	1,512	16.8
2013	439	2,847	235,651	82.73	5	5	21	4.2	32	119	2,785	23.4

2014	404	3,061	308,472	100.77	3	3	26	8.67	31	106	2,638	24.89
2015	392	2,765	303,255	109.49	3	9	156	17.33	24	89	2,599	29.2
2016	353	2,245	275,016	115.51	n.d.	n.d.	n.d.	n.d.	18	73	1,366	18.49
2017	323	2,180	229,469	105.26	4	4	15	3.75	23	121	4,484	37.06
10-year avg.	**404**	**2,768**	**246,960**	**88.63**	**10**	**19**	**665**	**35.24**	**23**	**82**	**2,076**	**25.32**
20- year avg.	**402**	**2,958**	**246,985**	**83.27**	**11**	**20**	**541**	**27.05**	**19**	**60**	**1,348**	**22.47**

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

1.2 NON-DEEP 7 BMUS

1.2.1 Fishery Descriptions

This species group is characterized by three jacks: the white/giant ulua (*Caranx ignobilis*), gunkan/black ulua (*Caranx lugubris*), and butaguchi/pig-lip ulua (*Pseudocaranx dentex*). The group is similarly characterized by two snappers: the uku (*Aprion virescens*) and yellowtail kalekale (*Pristipomoides auricilla*). All three jack species have been identified in local catch records since 1981. Before then, landings for these jack species were reported under the "miscellaneous jack" category, which has been summarized in the CREMUS group. The yellowtail kalekale was identified in the catch records starting in 1996. Previously, this species may have been reported as a general kalekale (*Pristipomoides sieboldii*), which has been summarized in the Deep 7 BMUS group.

Jacks are predators and found throughout the MHI, although the black ulua and butaguchi are relatively more abundant in the NWHI. In terms of habitat, white ulua prefer nearshore with rocky substrate, embayments, reefs, shallow, and deep waters. Butaguchi ulua forage in deeper waters near the bottom, and gunkan ulua similarly prefer deeper waters off reef slopes. The peak spawning period for white ulua is during new and full moons between May and August (Mitchell *et al.,* 2005).

1.2.2 Dashboard Statistics

The collection of commercial non-Deep 7 BMUS 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). The non-Deep7 BMUS 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.

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

Table 8. Annual fishing parameters for the 2017 fishing year in the MHI non-Deep 7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages.

Fishery	Parameters	2017 Values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
BMUS Non-Deep 7	No. License	412	↓ 7.21%	↑ 0.24%
	Trips	1,952	↓ 2.74%	↑ 10.5%
	No. Caught	16,573	↑ 20.1%	↑ 44.3%
	Lbs. Caught	127,265	↑ 5.38%	↑ 25.3%

1.2.2.2 Species Summary

Table 9. Annual fishing parameters for the 2017 fishing year in the MHI non-Deep 7 bottomfish fishery compared with short-term (10-year) and long-term (20-year) averages.

Methods	Fishery indicators	2017 values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Deep-Sea Handline	Uku	76,658 lbs.	↑ 12.6%	↑ 25.7%
	White Ulua	1,356 lbs.	↓ 66.5%	↓ 47.4%
	No. Lic.	187	↓ 7.43%	↓ 8.33%
	No. Trips	858	↓ 2.05%	↑ 2.14%
	Lbs. Caught	78,136 lbs.	↑ 6.70%	↑ 18.2%
	CPUE	91.07 lbs./trip	↑ 8.94%	↑ 15.7%
Inshore Handline	Uku	11,741 lbs.	↑ 1.7%	↑ 14.9%
	White Ulua	1,204 lbs.	↓ 54.6%	↓ 37.9%
	No. Lic.	58	↓ 37.6%	↓ 46.3%
	No. Trips	324	↓ 13.6%	↓ 18.4%
	Lbs. Caught	15,982 lbs.	↓ 7.39%	↑ 7.45%
	CPUE	49.33 lbs./trip	↑ 7.19%	↑ 31.7%
Troll with Bait	Uku	11,777 lbs.	↑ 69.5%	↑ 77.6%
	White Ulua	1,279 lbs.	↓ 27.9%	↓ 19.3%
	No. Lic.	34	↓ 8.11%	N/A
	No. Trips	169	↓ 4.50%	N/A
	Lbs. Caught	13,200 lbs.	↑ 51.1%	N/A
	CPUE	78.11 lbs./trip	↑ 58.2%	N/A

N/A = Insufficient data to report a 20-year trend.

1.2.3 Time Series Statistics

1.2.3.1 Commercial Fishing Parameters

The most important species in this MHI non-Deep 7 bottomfish fishery is the uku. Because of the wide habitat range where this species is found, it is commonly taken by heavy (deep-sea handline) and light (inshore handline) tackles and troll gear. The white ulua, gunkan ulua, and butaguchi ulua, and yellowtail kalekale were not established as specific species during data collection for the entire time series (see Section 1.2.1). From early on in the time series up until 1982, the effort and catch trends presented reflect only uku landings. The white ulua was not widely accepted by markets during the 1990s because of the ciguatera toxin. Since the implementation of the federal bottomfish fishing year, uku landings have trended upwards. During the first four federal fishing years, the Deep 7 bottomfish fishery was closed because the TAC or ACL was reached before the end of the fishing year. Bottomfishers shifted target to uku during these closures, and doing so recently has continued to be rewarding due good market price.

Table 10. HDAR MHI fiscal annual non-Deep 7 bottomfish commercial fishermen reports (1966-2017).

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1966	84	571	278	1,297	46,816
1967	108	733	366	1,911	64,215
1968	110	570	317	1,222	52,352
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	1,039	632	3,768	72,953
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	361	1,483	902	5,140	63,980
1981	392	2,117	1,107	7,950	95,027
1982	389	2,021	1,120	7,945	96,144
1983	431	2,769	1,366	10,880	123,244
1984	469	2,631	1,312	14,199	164,464
1985	467	2,112	1,157	8,905	101,889
1986	363	1,566	859	6,064	83,164
1987	366	1,586	887	10,700	117,959
1988	461	2,713	1,260	15,511	201,383
1989	509	3,317	1,621	31,063	347,700
1990	488	2,522	1,391	12,746	150,809
1991	454	2,189	1,258	12,183	144,940
1992	409	1,812	1,072	9,399	101,683
1993	365	1,498	897	6,811	76,343
1994	386	1,515	919	6,981	89,516
1995	395	1,710	954	7,961	85,106
1996	340	1,248	830	7,085	73,067
1997	448	1,901	1,144	10,147	93,482
1998	418	1,696	1,011	6,883	63,243
1999	366	1,458	916	9,639	84,116
2000	418	1,791	1,048	12,550	103,673
2001	374	1,520	924	9,392	78,113
2002	313	1,190	779	8,733	82,572
2003	329	1,223	780	7,064	66,225

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
2004	355	1,436	898	7,822	76,849
2005	381	1,557	946	10,587	95,028
2006	382	1,478	912	8,926	80,867
2007	357	1,706	958	9,832	96,223
2008	384	1,815	980	12,438	107,483
2009	411	1,725	1,018	11,399	97,130
2010	457	2,019	1,167	15,007	125,417
2011	494	2,374	1,325	16,402	149,144
2012	455	2,009	1,181	13,690	124,217
2013	493	2,113	1,274	17,378	157,798
2014	461	1,997	1,201	12,050	104,390
2015	460	2,092	1,236	14,631	123,931
2016	457	2,174	1,238	14,931	118,960
2017	412	1,952	1,135	16,573	127,265
10-year avg.	**444**	**2,007**	**1,160**	**13,800**	**120,771**
20-year avg.	**411**	**1,766**	**1,048**	**11,487**	**101,594**

1.2.4 Top Two Species per Gear Type

1.2.4.1 Deep-Sea Handline

Table 11. HDAR MHI fiscal annual non-Deep 7 bottomfish catch (lbs.) summary (1966-2017) by species and top gear: deep-sea handline.

Fiscal Year	Uku		White ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	78	46,358	NULL	NULL
1967	101	63,303	NULL	NULL
1968	104	51,705	NULL	NULL
1969	107	52,824	NULL	NULL
1970	115	48,645	NULL	NULL
1971	133	48,038	NULL	NULL
1972	154	53,336	NULL	NULL
1973	161	45,817	NULL	NULL
1974	216	72,130	NULL	NULL
1975	191	74,325	NULL	NULL
1976	166	63,048	NULL	NULL
1977	187	36,177	NULL	NULL
1978	303	75,501	NULL	NULL
1979	248	67,218	NULL	NULL
1980	290	57,725	NULL	NULL
1981	338	90,177	NULL	NULL

Fiscal Year	Uku		White ulua	
	No. License	**Lbs. Caught**	**No. License**	**Lbs. Caught**
1982	355	88,334	15	426
1983	368	109,638	31	5,284
1984	381	134,395	49	8,369
1985	360	84,510	37	3,789
1986	267	62,839	20	1,253
1987	246	61,087	15	4,466
1988	347	166,300	29	3,193
1989	422	297,514	67	15,715
1990	374	121,439	63	10,686
1991	322	104,580	58	7,316
1992	281	68,668	13	1,368
1993	221	54,888	9	712
1994	270	69,806	12	1,333
1995	275	61,449	13	501
1996	224	51,617	19	2,037
1997	250	56,910	12	923
1998	228	37,599	5	416
1999	215	64,511	8	466
2000	252	78,851	8	403
2001	205	50,998	10	608
2002	176	58,177	7	1,313
2003	153	41,730	28	2,120
2004	133	47,695	29	1,966
2005	160	55,707	33	1,519
2006	167	46,767	29	1,415
2007	162	51,603	34	4,052
2008	167	53,056	35	4,405
2009	183	65,897	40	3,462
2010	200	75,714	51	4,113
2011	234	88,939	57	7,033
2012	206	65,393	42	4,319
2013	203	89,061	40	5,475
2014	174	57,181	35	3,104
2015	174	69,025	30	2,603
2016	173	64,206	28	1,826
2017	182	76,658	24	1,356
10-year avg.	**188**	**68,080**	**39**	**4,042**
20-year avg.	**191**	**60,988**	**28**	**2,579**

1.2.4.2 Inshore Handline

Table 12. HDAR MHI fiscal annual non-Deep 7 bottomfish catch (lbs.) summary (1966-2017) by species and top gear: inshore handline.

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	4	50	NULL	NULL
1967	4	554	NULL	NULL
1968	8	345	NULL	NULL
1969	3	24	NULL	NULL
1970	3	20	NULL	NULL
1971	3	25	NULL	NULL
1972	3	12	NULL	NULL
1973	8	47	NULL	NULL
1974	7	158	NULL	NULL
1975	16	331	NULL	NULL
1976	42	2,453	NULL	NULL
1977	60	7,792	NULL	NULL
1978	134	14,348	NULL	NULL
1979	211	12,673	NULL	NULL
1980	71	1,825	NULL	NULL
1981	67	1,198	NULL	NULL
1982	43	582	n.d.	n.d.
1983	45	560	6	182
1984	53	1,169	8	1,062
1985	4	207	3	91
1986	22	2,323	4	147
1987	91	11,687	14	537
1988	91	10,401	14	661
1989	75	4,532	10	415
1990	78	2,653	10	297
1991	106	4,675	23	973
1992	127	17,553	12	864
1993	114	8,222	13	552
1994	83	8,333	7	169
1995	98	8,413	11	436
1996	85	4,668	10	926
1997	175	14,612	14	1,206
1998	173	17,614	14	1,427
1999	134	10,050	12	930
2000	152	14,423	11	609

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
2001	142	14,844	17	827
2002	94	12,229	18	1,291
2003	70	6,748	24	1,458
2004	68	5,063	31	1,431
2005	80	6,980	24	1,856
2006	64	9,098	20	1,275
2007	64	10,452	21	1,642
2008	67	13,079	33	2,619
2009	91	9,148	36	2,446
2010	86	15,368	40	3,039
2011	102	17,679	47	5,070
2012	89	20,860	31	4,594
2013	88	21,188	37	2,174
2014	78	12,968	29	1,549
2015	63	11,917	23	1,353
2016	64	12,188	21	1,581
2017	44	14,741	23	1,204
10-year avg.	**80**	**14,498**	**32**	**2,649**
20-year avg.	**97**	**12,832**	**25**	**1,940**

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

1.2.4.3 Troll with Bait

The gear code for troll with bait was established in October 2002 when the revised commercial fishing reports were implemented. Previously all troll activities were reported as "miscellaneous troll gear".

Table 13. HDAR MHI fiscal annual non-Deep 7 bottomfish catch (lbs.) summary (1966-2017) by species and top gear: troll with bait.

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
2003	19	2,270	11	1,034
2004	17	5,664	8	1,365
2005	21	9,041	6	1,036
2006	17	6,361	8	994
2007	12	4,842	16	1,837
2008	13	13,599	14	2,090
2009	15	2,470	14	1,292

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
2010	26	5,813	12	1,493
2011	31	3,679	17	2,075
2012	26	5,315	13	1,885
2013	40	6,840	16	2,482
2014	45	6,334	18	2,177
2015	45	9,004	12	1,294
2016	47	11,597	16	1,125
2017	29	11,777	11	1,279
10-year avg.	**30**	**6,949**	**15**	**1,775**
20-year avg.	**27**	**6,631**	**13**	**1,584**

1.2.4.4 Troll (Misc.)

The troll gear was standardized and reported under specific methods including troll with lure or bait or green stick in October 2002 when the revised commercial fishing reports were implemented. Since then, fishers have been contacted to verify miscellaneous troll activities on their fishing reports. A fishing report would not be amended if the associated fisher did not respond.

Table 14. HDAR MHI fiscal annual non-Deep 7 bottomfish catch (lbs.) summary (1966-2017) by species and top gear: miscellaneous troll. Recent data restricted by confidentiality protocol.

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1972	5	142	NULL	NULL
1973	5	204	NULL	NULL
1974	12	326	NULL	NULL
1975	16	283	NULL	NULL
1976	20	2,206	NULL	NULL
1977	26	955	NULL	NULL
1978	20	1,374	NULL	NULL
1979	n.d.	n.d.	NULL	NULL
1980	51	1,748	NULL	NULL
1981	29	1,125	NULL	NULL
1982	27	1,329	6	470
1983	29	1,429	7	185
1984	42	2,563	34	1689
1985	9	380	83	4568
1986	23	634	48	2616

Fiscal Year	Uku		White Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1987	24	1,777	15	3731
1988	29	2,877	15	852
1989	49	6,196	18	1,389
1990	52	3,063	17	1,978
1991	41	5,991	27	2,007
1992	38	3,867	13	339
1993	24	932	10	872
1994	34	1,155	7	553
1995	37	1,028	4	261
1996	33	1,562	6	327
1997	47	2,411	6	556
1998	33	675	5	257
1999	23	1,724	4	369
2000	31	1,359	7	184
2001	40	2,340	9	1,129
2002	37	2,040	6	476
2003	10	373	3	115
2004	3	43	NULL	NULL
2005	NULL	NULL	n.d.	n.d.
2006	NULL	NULL	NULL	NULL
2007	NULL	NULL	NULL	NULL
2008	NULL	NULL	NULL	NULL
2009	NULL	NULL	NULL	NULL
2010	NULL	NULL	NULL	NULL
2011	NULL	NULL	NULL	NULL
2012	NULL	NULL	NULL	NULL
2013	NULL	NULL	n.d.	n.d.
2014	NULL	NULL	NULL	NULL
2015	NULL	NULL	NULL	NULL
2016	NULL	NULL	NULL	NULL
2017	NULL	NULL	NULL	NULL

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

1.2.5 Catch Parameters by Gear

Uku is the driver species in the non-Deep 7 bottomfish group, and it is commonly caught by the following top dominant gears: deep-sea handline, inshore handline, trolling with bait, and miscellaneous trolling. Landings of uku along with the Deep 7 bottomfish species peaked in 1989 for the deep-sea handline gear. A second peak for this gear type occurred in 2013 due to bottomfishers shifting their fishing target to uku during the summer months.

Table 15. Time series of CPUE by dominant fishing methods from non-Deep 7 BMUS (1966-2016).

Fiscal Year	Deep-sea handline				Inshore handline				Troll with bait				Troll (misc.)			
	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE
1966	78	514	46,358	90.19	4	4	50	12.5	NULL	NULL	NULL	0	NULL	NULL	NULL	0
1967	101	683	63,303	92.68	4	5	554	110.8	NULL	NULL	NULL	0	n.d.	n.d.	n.d.	n.d.
1968	104	509	51,705	101.58	8	13	345	26.54	NULL	NULL	NULL	0	n.d.	n.d.	n.d.	n.d.
1969	107	615	52,824	85.89	3	3	24	8	NULL	NULL	NULL	0	n.d.	n.d.	n.d.	n.d.
1970	115	633	48,645	76.85	3	4	20	5	NULL	NULL	NULL	0	NULL	NULL	NULL	0
1971	133	548	48,038	87.66	3	4	25	6.25	NULL	NULL	NULL	0	NULL	NULL	NULL	0
1972	154	663	53,336	80.45	3	3	12	4	NULL	NULL	NULL	0	5	10	142	14.2
1973	161	675	45,817	67.88	8	9	47	5.22	NULL	NULL	NULL	0	5	7	204	29.14
1974	216	968	72,130	74.51	7	10	158	15.8	NULL	NULL	NULL	0	12	13	326	25.08
1975	191	947	74,325	78.48	16	23	331	14.39	NULL	NULL	NULL	0	16	19	283	14.89
1976	166	732	63,048	86.13	42	97	2,453	25.29	NULL	NULL	NULL	0	20	52	2,206	42.42
1977	187	716	36,177	50.53	60	211	7,792	36.93	NULL	NULL	NULL	0	26	41	955	23.29
1978	303	1,097	75,501	68.82	134	298	14,348	48.15	NULL	NULL	NULL	0	20	41	1,374	33.51
1979	248	857	67,218	78.43	211	431	12,673	29.4	NULL	NULL	NULL	0	n.d.	n.d.	n.d.	n.d.
1980	290	1,196	57,725	48.27	71	110	1,825	16.59	NULL	NULL	NULL	0	51	82	1,748	21.32
1981	338	1,763	90,177	51.15	67	110	1,198	10.89	NULL	NULL	NULL	0	29	44	1,125	25.57
1982	355	1,760	90,223	51.26	45	66	603	9.14	NULL	NULL	NULL	0	30	40	1,799	44.98
1983	374	2,506	115,980	46.28	51	74	748	10.11	NULL	NULL	NULL	0	36	46	1,614	35.09
1984	397	2,246	144,502	64.34	58	95	2,239	23.57	NULL	NULL	NULL	0	73	108	4,252	39.37
1985	378	1,853	92,057	49.68	8	8	306	38.25	NULL	NULL	NULL	0	91	133	4,948	37.2
1986	282	1,271	70,271	55.29	28	60	2,540	42.33	NULL	NULL	NULL	0	63	92	3,250	35.33
1987	262	1,084	82,513	76.12	100	264	12,376	46.88	NULL	NULL	NULL	0	35	75	5,555	74.07
1988	365	2,270	174,945	77.07	101	218	11,132	51.06	NULL	NULL	NULL	0	43	78	3,837	49.19
1989	441	2,867	320,763	111.88	83	174	4,955	28.48	NULL	NULL	NULL	0	62	116	7,585	65.39

Fiscal Year	Deep-sea handline				Inshore handline				Troll with bait				Troll (misc.)			
	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE	No. Lic.	No. trips	Lbs. Caught	CPUE
1990	395	2,053	139,989	68.19	83	232	3,136	13.52	NULL	NULL	NULL	0	67	113	5,041	44.61
1991	346	1,680	125,306	74.59	120	259	5,679	21.93	NULL	NULL	NULL	0	64	126	7,998	63.48
1992	289	1,169	72,393	61.93	130	445	18,434	41.42	NULL	NULL	NULL	0	48	79	4,206	53.24
1993	237	911	62,746	68.88	122	372	8,790	23.63	NULL	NULL	NULL	0	31	68	1,804	26.53
1994	282	1,086	76,244	70.21	85	218	8,502	39	NULL	NULL	NULL	0	39	63	1,708	27.11
1995	291	1,230	72,242	58.73	105	298	8,886	29.82	NULL	NULL	NULL	0	40	63	1,289	20.46
1996	234	811	61,442	75.76	92	250	5,668	22.67	NULL	NULL	NULL	0	39	67	1,889	28.19
1997	268	1,033	71,884	69.59	179	655	15,868	24.23	NULL	NULL	NULL	0	51	91	2,966	32.59
1998	238	905	40,551	44.81	183	619	19,302	31.18	NULL	NULL	NULL	0	39	59	978	16.58
1999	222	782	67,218	85.96	140	473	11,029	23.32	NULL	NULL	NULL	0	27	44	2,093	47.57
2000	258	996	83,039	83.37	158	567	15,049	26.54	NULL	NULL	NULL	0	36	47	1,543	32.83
2001	212	850	55,632	65.45	152	464	15,707	33.85	NULL	NULL	NULL	0	50	84	3,481	41.44
2002	187	697	62,685	89.94	106	335	13,562	40.48	NULL	NULL	NULL	0	43	71	2,536	35.72
2003	173	674	46,791	69.42	80	238	8,390	35.25	23	65	3,333	51.28	13	18	488	27.11
2004	150	644	51,079	79.2	85	275	6,614	24.05	21	118	7,075	59.96	3	3	43	14.33
2005	175	761	60,698	79.76	89	313	8,904	28.45	22	127	10,077	79.35	n.d.	n.d.	n.d.	n.d.
2006	173	691	50,233	72.7	71	246	10,481	42.61	24	108	7,385	68.38	NULL	NULL	NULL	0
2007	169	813	56,300	69.25	73	313	12,115	38.71	25	137	6,719	49.04	NULL	NULL	NULL	0
2008	189	840	60,670	72.23	83	334	15,869	47.51	21	199	15,689	78.84	NULL	NULL	NULL	0
2009	201	899	70,006	77.87	109	329	11,678	35.5	21	104	3,792	36.46	NULL	NULL	NULL	0
2010	217	911	81,054	88.97	99	388	18,439	47.53	32	142	7,306	51.45	NULL	NULL	NULL	0
2011	257	1,200	97,542	81.22	121	443	22,881	51.65	37	136	5,827	42.85	NULL	NULL	NULL	0
2012	223	807	70,811	87.75	100	465	25,724	55.52	29	157	7,199	45.85	NULL	NULL	NULL	0
2013	217	861	96,085	111.6	105	404	23,407	57.94	47	175	8,985	50.12	n.d.	n.d.	n.d.	n.d.
2014	184	807	60,699	75.35	88	341	14,787	43.36	51	222	8,511	38.34	NULL	NULL	NULL	0
2015	181	826	72,040	87.28	72	335	13,328	39.79	48	224	10,300	46.17	NULL	NULL	NULL	0

Fiscal Year	Deep-sea handline				Inshore handline				Troll with bait				Troll (misc.)			
	No. Lic.	**No. trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. trips**	**Lbs. Caught**	**CPUE**
2016	181	789	66,362	84.02	72	380	13,833	35.66	52	255	11,383	48.93	NULL	NULL	NULL	0
2017	187	858	78,136	91.07	58	324	15,982	49.33	34	169	13,200	78.11	NULL	NULL	NULL	0
10-year avg.	**202**	**876**	**73,232**	**83.6**	**93**	**375**	**17,258**	**46.02**	**37**	**177**	**8,739**	**49.37**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
20-year avg.	**204**	**840**	**66,107**	**78.7**	**108**	**397**	**14,874**	**37.47**	**33**	**156**	**8,233**	**52.78**	**26**	**42**	**1,415**	**33.69**

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

1.3 CREMUS FINFISH

1.3.1 Fishery Descriptions

There are 66 different specific finfish species in CREMUS group. These species represent a total of 12 families including surgeonfish (*Acanthuridae*), jacks (*Carangidae*), squirrelfish (*Holocentridae*), rudderfish (*Kyphosidae*), wrasses (*Labridae*), emperor (*Lethrinidae*), snappers (*Lutjanidae*), mullet (*Mugilidae*), goatfish (*Mullidae*), parrotfish (*Scaridae*), grouper (*Serranidae*), and shark (*Carcharhinidae)*.

Overall, the key driver species in this group category are the akule, halalu (juvenile akule), opelu from the Carangidae family, ta'ape from the Lutjanidae family, ama'ama from the Mugilidae family, and miscellaneous weke from the Mullidae family. The dominant gear types are inshore handline, purse seine net (pelagic), lay gill net, and seine net.

1.3.2 Dashboard Statistics

The collection of commercial CREMUS finfish 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). The CREMUS finfish 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.

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.

1.3.2.1 Historical Summary

Table 16. Annual fishing parameters for the 2017 fishing year in the MHI CREMUS fishery compared with short-term (10-year) and long-term (20-year) averages.

Fishery	Parameters	2017 Values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
CREMUS Finfish	No. License	601	↓ 20.6%	↓ 25.5%
	Trips	6,043	↓ 28.5%	↓ 32.5%
	No. Caught	1,085,267	↓ 22.5%	↑ 9.32%
	Lbs. Caught	720,182	↓ 29.5%	↓ 41.1%

1.3.2.2 Species Summary

Table 17. Annual fishing parameters for the 2017 fishing year in the MHI CREMUS fishery compared with short-term (10-year) and long-term (20-year) averages.

Methods	Fishery Indicators	2017 values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Inshore Handline	Opelu	22,367 lbs.	↓ 82.8%	↓ 85.0%
	Akule	76,650 lbs.	↓ 15.8%	↓ 32.9%
	Ta'ape	4,408 lbs.	↓ 29.7%	↓ 54.7%
	Ulua	N/A	N/A	N/A
	No. Lic.	180	↓ 43.0%	↓ 55.0%
	No. Trips	1,847	↓ 47.5%	↓ 58.9%
	Lbs. Caught	115,394 lbs.	↓ 52.7%	↓ 61.2%
	CPUE	62.48 lbs./trip	↓ 9.91%	↓ 5.62%
Purse Seine Net	Akule Ulua Kala Ta'ape	Insufficient data to report trends		
	No. Lic.	3	↓ 40%	↓ 50%
	No. Trips	21	↓ 16.0%	↓ 32.3%
	Lbs. Caught	39,501 lbs.	↓ 61.4%	↓ 71.6%
	CPUE	1,881 lbs./trip	↓ 54.0%	↓ 58.4%
Lay Gill Net	Akule	159,667 lbs.	↑ 13.6%	↑ 13.5%
	Weke	N/A	N/A	N/A
	Ama'ama	1,081 lbs.	↓ 85.6%	↓ 83.5%
	Kala	10,643 lbs.	↓ 1.01%	↑ 25.3%
	No. Lic.	27	↓ 25.0%	↓ 34.2%
	No. Trips	327	↓ 14.6%	↓ 31.9%
	Lbs. Caught	184,690 lbs.	↑ 2.38%	↓ 0.10%
	CPUE	564.8 lbs./trip	↑ 19.9%	↑ 46.6%
Seine Net	Akule	61,062 lbs.	↑ 12.6%	↓ 67.4%
	Weke	N/A	N/A	N/A
	Ta'ape	20,358 lbs.	↑ 13.0%	↑ 24.0%
	Opelu	N/A	N/A	N/A
	No. Lic.	19	↓ 20.8%	↓ 9.52%
	No. Trips	191	↓ 16.2%	↓ 4.02%
	Lbs. Caught	134,735 lbs.	↓ 8.14%	↓ 49.5%
	CPUE	705.42 lbs./trip	↑ 9.65%	↓ 47.4%
Spear	Uhu	16,036 lbs.	↓ 62.0%	↓ 47.0%
	Palani	8,869 lbs.	↓ 35.6%	↓ 8.88%
	Kala	5,135 lbs.	↓ 51.3%	↓ 31.2%
	Manini	4,412 lbs.	↓ 42.0%	↓ 18.0%
	No. Lic.	65	↓ 35.0%	↓ 36.9%
	No. Trips	666	↓ 43.5%	↓ 31.1%
	Lbs. Caught	53	↓ 53.7%	↓ 34.1%
	CPUE	79.87 lbs./trip	↓ 17.9%	↓ 4.31%

1.3.3 Time Series Statistics

1.3.3.1 Commercial Fishing Parameters

Table 18. Time series of commercial fishermen reports for the CREMUS finfish fishery (1966-2017).

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1966	261	6,387	1,482	329,614	1,114,853
1967	302	7,324	1,731	325,083	1,328,133
1968	294	6,463	1,634	302,805	1,512,844
1969	362	7,038	1,802	411,936	1,628,970
1970	417	7,870	2,113	371,275	1,469,487
1971	478	7,671	2,171	304,742	1,332,051
1972	488	8,288	2,369	318,812	1,287,455
1973	538	7,488	2,328	352,780	1,269,877
1974	646	8,290	2,684	353,026	1,115,435
1975	648	8,872	2,657	427,742	1,159,570
1976	684	9,047	2,839	353,277	1,378,855
1977	772	10,321	3,172	423,391	1,577,768
1978	942	8,739	3,928	461,673	1,315,632
1979	955	6,460	4,072	462,099	1,171,970
1980	954	9,315	3,771	536,639	1,410,824
1981	989	11,968	3,967	495,199	1,350,879
1982	868	10,477	3,602	269,481	1,075,781
1983	956	12,482	4,017	339,593	1,493,283
1984	1,037	12,511	4,145	269,324	1,475,465
1985	925	11,057	3,757	297,806	921,552
1986	996	11,149	3,984	272,007	848,528
1987	1,010	11,758	3,973	350,436	994,022
1988	1,029	11,671	4,034	268,120	960,842
1989	1,090	12,125	4,370	336,536	1,222,961
1990	1,051	12,046	4,183	450,386	1,477,667
1991	1,059	12,079	4,151	348,003	1,341,206
1992	1,055	12,513	4,122	443,298	1,547,351
1993	987	10,497	3,551	208,924	1,396,986
1994	1,036	10,522	3,688	162,596	1,152,157
1995	1,038	10,543	3,626	148,510	1,397,121
1996	1,058	11,514	3,818	178,477	1,382,267
1997	1,110	12,081	4,172	194,210	1,243,396
1998	1,097	12,313	4,111	346,507	1,953,487
1999	1,015	10,881	3,701	251,043	1,861,426
2000	953	11,067	3,552	353,755	1,795,017

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
2001	889	9,845	3,292	290,579	1,516,577
2002	808	8,378	2,972	221,654	1,064,347
2003	736	8,347	2,700	1,181,409	1,268,654
2004	687	8,224	2,612	1,155,922	1,231,904
2005	648	7,023	2,349	890,187	1,210,960
2006	634	6,500	2,178	956,258	1,095,354
2007	641	7,678	2,416	1,648,856	1,301,579
2008	646	7,534	2,438	1,664,832	1,071,304
2009	806	8,798	3,018	1,642,692	908,931
2010	824	9,983	3,276	1,391,746	1,074,816
2011	851	9,789	3,312	1,303,543	1,187,856
2012	779	8,972	3,031	1,324,037	947,831
2013	793	8,515	3,011	1,204,777	932,060
2014	761	8,083	2,920	1,195,820	883,302
2015	761	7,655	2,877	1,181,857	912,322
2016	699	7,316	2,730	1,345,114	923,042
2017	601	6,043	2,365	1,085,267	720,182
10-year avg.	**757**	**8,447**	**2,908**	**1,401,234**	**1,021,039**
20-year avg.	**807**	**8,957**	**3,036**	**992,715**	**1,222,587**

1.3.4 Top 4 Species per Gear Type

1.3.4.1 Inshore Handline

Table 19. HDAR MHI fiscal annual CREMUS finfish catch (lbs.) summary (1966-2017) by species and top gear: inshore handline.

Fiscal Year	Opelu		Akule		Ta'ape		Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	88	89,408	110	160,301	NULL	NULL	57	4,879
1967	109	136,450	118	155,720	NULL	NULL	64	4,863
1968	87	104,308	111	174,282	NULL	NULL	59	5,076
1969	89	128,720	134	188,541	NULL	NULL	83	5,988
1970	100	114,741	141	164,990	5	534	76	5,921
1971	111	97,302	158	150,492	25	1,546	73	3,832
1972	140	120,995	190	174,260	40	1,602	104	4,957
1973	137	92,282	182	147,072	48	1,822	96	4,202
1974	139	89,675	202	142,495	54	2,065	107	4,517
1975	143	164,833	201	159,815	66	3,262	91	5,461
1976	123	152,760	166	126,854	58	2,844	96	6,351

Fiscal Year	Opelu		Akule		Ta‘ape		Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1977	119	122,355	138	52,421	77	2,298	93	4,617
1978	156	186,552	194	97,186	232	18,596	182	11,917
1979	138	172,771	238	109,071	244	20,643	251	20,628
1980	180	246,393	226	94,969	209	11,943	156	9,651
1981	195	217,082	237	109,449	200	13,603	180	11,898
1982	173	133,747	235	97,257	242	14,386	172	8,576
1983	164	114,400	322	162,519	246	16,390	167	6,885
1984	207	235,467	295	150,735	272	17,387	215	8,003
1985	182	151,699	214	101,670	191	14,188	142	8,507
1986	250	193,535	224	73,529	257	19,526	137	6,838
1987	289	252,473	222	78,773	197	16,682	159	10,156
1988	227	148,241	211	82,828	226	20,170	151	6,489
1989	228	142,750	207	90,862	173	7,112	163	10,831
1990	227	156,300	309	141,707	183	8,412	118	3,820
1991	212	184,668	310	203,420	250	13,989	155	6,751
1992	323	227,866	372	207,980	219	14,286	154	16,812
1993	243	205,254	322	154,577	194	12,284	121	12,166
1994	299	211,838	266	133,564	204	14,430	107	7,811
1995	222	176,137	245	103,124	201	19,664	132	12,875
1996	344	276,576	295	148,925	207	14,429	103	7,196
1997	327	230,136	361	179,306	255	16,995	182	13,587
1998	241	159,954	350	203,059	277	21,573	177	22,456
1999	208	170,547	293	195,973	212	17,345	142	16,322
2000	225	185,713	284	185,869	193	21,144	117	7,575
2001	214	185,394	239	140,482	176	20,370	123	14,019
2002	194	152,356	200	108,446	145	11,760	112	9,591
2003	209	214,377	151	107,384	115	6,835	44	2,661
2004	176	163,963	145	100,022	97	5,770	5	171
2005	141	100,965	103	83,258	89	5,212	14	369
2006	140	117,589	98	69,912	84	4,747	n.d	n.d.
2007	187	172,586	117	87,912	87	4,846	n.d	n.d.
2008	140	143,692	105	65,024	100	6,282	3	100
2009	213	178,821	154	80,157	124	8,158	n.d	n.d.
2010	197	159,413	171	121,585	124	8,975	6	195
2011	188	168,377	150	90,770	114	8,368	NULL	NULL
2012	166	117,301	162	91,604	116	9,003	NULL	NULL
2013	172	119,257	153	92,126	110	6,238	NULL	NULL
2014	161	96,798	129	79,606	88	3,612	n.d	n.d.

Fiscal Year	Opelu		Akule		Ta'ape		Ulua	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
2015	102	80,284	128	98,014	73	3,819	9	230
2016	86	61,494	119	100,223	57	3,058	4	63
2017	51	22,367	104	76,650	66	4,408	NULL	NULL
10-year avg.	**162**	**129,816**	**139**	**90,984**	**100**	**6,274**	**4**	**113**
20-year avg.	**185**	**148,967**	**181**	**114,178**	**132**	**9,725**	**53**	**4,872**

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

1.3.4.2 Purse Seine Net (Pelagic)

The purse seine net (pelagic) gear was standardized in October 2002 when the revised fishing reports were implemented. This gear was formerly called the akule or bag net, and is utilized by surrounding a school of fish with a net and drawing the bottom of the net closed to form a bag. In recent years, this method has been used by a few highliners to land large volumes of akule. The largest operation ended a several years ago with the vessel being converted for use in the longline fleet. Recent annual landings for some species may not be available due to data confidentiality. Fishers who use a gear type where the fish get tangled in mesh will typically opt to report the method as gill net.

Table 20. HDAR MHI fiscal annual CREMUS finfish catch (lbs.) summary (1966-2017) by species and second gear: pelagic purse seine net.

Fiscal Year	Akule		Ulua (misc.)		Kala		Ta'ape	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	9	430,069	n.d.	n.d.	NULL	NULL	NULL	NULL
1967	8	541,816	3	10,163	n.d.	n.d.	NULL	NULL
1968	19	802,810	4	6,860	3	5,214	NULL	NULL
1969	22	575,744	5	14,359	5	3,822	NULL	NULL
1970	32	764,641	n.d.	n.d.	5	3,168	NULL	NULL
1971	14	604,113	3	1,332	3	4,500	NULL	NULL
1972	19	527,806	n.d.	n.d.	4	335	NULL	NULL
1973	27	563,319	4	1919	n.d.	n.d.	NULL	NULL
1974	25	331,655	n.d.	n.d.	n.d.	n.d.	NULL	NULL
1975	21	233,349	4	341	n.d.	n.d.	n.d.	n.d.
1976	37	136,603	3	4,607	n.d.	n.d.	n.d.	n.d.
1977	24	369,813	NULL	NULL	n.d.	n.d.	NULL	NULL
1978	15	235,862	n.d.	n.d.	n.d.	n.d.	NULL	NULL
1979	27	198,657	NULL	NULL	n.d.	n.d.	NULL	NULL

Fiscal Year	Akule		Ulua (misc.)		Kala		Ta‘ape	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1980	25	271,103	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1981	24	100,923	NULL	NULL	NULL	NULL	NULL	NULL
1982	18	159,716	NULL	NULL	NULL	NULL	NULL	NULL
1983	26	152,571	NULL	NULL	NULL	NULL	n.d.	n.d.
1984	31	322,873	n.d.	n.d.	3	1028	NULL	NULL
1985	13	46,523	n.d.	n.d.	NULL	NULL	NULL	NULL
1986	6	53,683	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1987	13	19,779	n.d.	n.d.	NULL	NULL	NULL	NULL
1988	12	10,660	NULL	NULL	NULL	NULL	NULL	NULL
1989	25	262,304	NULL	NULL	NULL	NULL	NULL	NULL
1990	21	105,824	n.d.	n.d.	NULL	NULL	NULL	NULL
1991	26	102,669	NULL	NULL	NULL	NULL	NULL	NULL
1992	16	47,720	NULL	NULL	NULL	NULL	NULL	NULL
1993	8	23,160	NULL	NULL	NULL	NULL	NULL	NULL
1994	12	29,766	NULL	NULL	NULL	NULL	NULL	NULL
1995	18	294,130	NULL	NULL	NULL	NULL	NULL	NULL
1996	14	276,916	NULL	NULL	NULL	NULL	NULL	NULL
1997	9	50,949	NULL	NULL	NULL	NULL	NULL	NULL
1998	7	27,496	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1999	5	55,633	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2000	6	105,037	NULL	NULL	NULL	NULL	NULL	NULL
2001	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
2002	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2003	3	286,796	NULL	NULL	n.d.	n.d.	n.d.	n.d.
2004	6	276,164	NULL	NULL	NULL	NULL	n.d.	n.d.
2005	5	427,938	NULL	NULL	n.d.	n.d.	n.d.	n.d.
2006	4	356,297	NULL	NULL	NULL	NULL	NULL	NULL
2007	3	374,871	NULL	NULL	NULL	NULL	NULL	NULL
2008	n.d.	n.d.	NULL	NULL	NULL	NULL	n.d.	n.d.
2009	4	98,213	NULL	NULL	n.d.	n.d.	n.d.	n.d.
2010	8	52,604	NULL	NULL	NULL	NULL	NULL	NULL
2011	n.d.	n.d.	NULL	NULL	n.d.	n.d.	n.d.	n.d.
2012	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
2013	n.d.	n.d.	NULL	NULL	NULL	NULL	n.d.	n.d.
2014	NULL	NULL	NULL	NULL	NULL	NULL	n.d.	n.d.
2015	4	23,735	NULL	NULL	NULL	NULL	n.d.	n.d.
2016	n.d.	n.d.	NULL	NULL	NULL	NULL	n.d.	n.d.
2017	3	39,401	NULL	NULL	NULL	NULL	n.d.	n.d.

Fiscal Year	Akule		Ulua (misc.)		Kala		Ta‘ape	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
10-year avg.	**3**	**102,526**	**NULL**	**NULL**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
20-year avg.	**4**	**139,439**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**

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

1.3.4.3 Lay Gill Net

The lay gill net gear was standardized in October 2002 when the revised fishing reports were implemented. This gear type is characterized more by methodology than it is equipment, as it is net that captures fish by entangling the fish head in the mesh. Consequently, most fishers who use mesh net and entangle the fish will report this method.

Table 21. HDAR MHI fiscal annual CREMUS finfish catch (lbs.) summary (1966-2017) by species and third gear: lay gill net.

Fiscal Year	Akule		Weke (misc.)		Ama‘ama		Kala	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	9	22,711	23	6,421	25	14,090	9	777
1967	6	14,380	26	10,865	25	19,491	12	2,789
1968	13	48,949	29	12,389	19	16,964	9	633
1969	17	37,858	43	11,405	30	22,603	11	2,709
1970	17	35,368	56	24,342	35	14,449	19	7,326
1971	22	86,067	54	16,467	36	17,357	23	6,038
1972	27	104,361	49	15,346	34	15,600	29	10,785
1973	35	94,435	68	21,882	42	13,898	24	7,127
1974	53	148,772	71	23,164	41	15,358	40	18,656
1975	53	188,093	61	27,097	44	12,100	51	15,742
1976	35	139,046	66	27,985	28	11,021	46	10,705
1977	47	208,639	79	24,005	35	13,304	51	10,827
1978	51	144,587	87	31,425	46	13,230	58	16,611
1979	33	92,734	84	15,208	38	15,676	45	8,606
1980	32	170,266	70	37,174	39	8,369	47	8,049
1981	31	173,429	73	55,584	36	8,031	42	6,728
1982	22	80,563	62	36,216	40	6,900	39	5,362
1983	29	166,452	58	32,332	33	5,723	36	6,678
1984	36	142,881	62	28,323	35	3,998	31	2,622
1985	22	109,702	31	8,541	16	2,581	19	1,383
1986	19	61,882	22	6,857	17	1,773	14	2,622
1987	13	26,469	22	9,146	22	3,721	13	7,782

Fiscal Year	Akule		Weke (misc.)		Ama'ama		Kala	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1988	19	21,536	30	8,386	17	1,296	15	8,313
1989	22	33,648	43	11,727	13	1,427	28	4,542
1990	26	223,344	23	7,052	15	2,046	11	326
1991	27	114,547	30	6,467	12	276	21	2,481
1992	33	155,760	36	8,836	14	7,820	21	2,086
1993	35	158,397	34	11,727	14	8,500	15	2,726
1994	30	131,655	35	5,767	14	5,636	26	2,396
1995	28	99,625	36	10,008	16	4,658	17	1,747
1996	25	109,947	36	19,069	14	6,026	31	7,245
1997	27	182,017	29	11,848	16	4,904	25	3,779
1998	23	205,954	24	6,283	10	5,469	17	3,986
1999	25	198,943	22	6,960	13	3,537	12	1,130
2000	23	217,039	18	2,851	14	2,862	15	4,291
2001	27	140,410	20	2,448	11	5,759	15	9,788
2002	20	42,247	14	3,875	9	5,423	13	8,110
2003	20	97,978	12	4,592	12	7,054	15	11,198
2004	19	114,786	8	2,021	11	7,089	12	4,918
2005	25	135,373	7	450	11	8,214	14	7,841
2006	17	74,215	n.d.	n.d.	11	6,116	15	7,357
2007	15	128,642	NULL	NULL	6	8,515	11	8,193
2008	16	112,086	NULL	NULL	10	11,905	5	6,109
2009	16	59,712	3	206	10	8,102	9	6,123
2010	19	112,663	4	1,152	12	6,038	10	11,105
2011	21	169,952	n.d.	n.d.	8	6,177	12	12,392
2012	19	153,280	n.d.	n.d.	4	14,111	12	10,453
2013	23	128,601	NULL	NULL	12	5,400	10	16,716
2014	14	144,310	NULL	NULL	11	5,802	12	10,367
2015	23	206,132	NULL	NULL	8	5,141	11	13,473
2016	19	187,154	NULL	NULL	6	3,601	6	12,364
2017	21	159,667	NULL	NULL	4	1,081	6	10,643
10-year avg.	**19**	**140,553**	**n.d.**	**n.d.**	**9**	**7,481**	**10**	**10,752**
20-year avg.	**21**	**140,725**	**11**	**2,989**	**10**	**6,562**	**13**	**8,496**

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

1.3.4.4 Seine Net

The seine net gear was standardized in October 2002 when the revised fishing reports were implemented. This gear is defined as using a net by moving it through the water to surround a school of fish, corral them, and trap them within the net. Fishers who use this type of gear where the fish end up being entangled in the mesh will typically opt to report the method as gill net.

Table 22. HDAR MHI fiscal annual CREMUS finfish catch (lbs.) summary (1966-2017) by species and fourth gear: seine net.

Fiscal Year	Akule		Weke (misc.)		Ta‘ape		Opelu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	n.d.	n.d.	3	5,214	NULL	NULL	n.d.	n.d.
1967	n.d.	n.d.	4	4,654	NULL	NULL	n.d.	n.d.
1968	n.d.	n.d.	3	683	NULL	NULL	n.d.	n.d.
1969	3	17,337	5	3,339	NULL	NULL	n.d.	n.d.
1970	n.d.	n.d.	3	1,179	NULL	NULL	n.d.	n.d.
1971	n.d.	n.d.	3	1,519	NULL	NULL	n.d.	n.d.
1972	n.d.	n.d.	3	383	NULL	NULL	n.d.	n.d.
1973	n.d.	n.d.	3	336	NULL	NULL	n.d.	n.d.
1974	3	14,740	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1975	n.d.	n.d.	NULL	NULL	NULL	NULL	n.d.	n.d.
1976	n.d.	n.d.	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1977	5	74,825	4	1,800	n.d.	n.d.	n.d.	n.d.
1978	n.d.	n.d.	10	21,233	4	12,207	NULL	NULL
1979	n.d.	n.d.	19	30,891	15	17,900	n.d.	n.d.
1980	n.d.	n.d.	12	17,748	6	7,372	n.d.	n.d.
1981	NULL	NULL	8	7,508	n.d.	n.d.	NULL	NULL
1982	5	21,701	9	14,804	6	14,106	n.d.	n.d.
1983	6	48,543	11	14,865	6	14,837	n.d.	n.d.
1984	6	41,584	5	7,539	3	1,355	NULL	NULL
1985	4	7,548	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1986	n.d.	n.d.	3	8,168	n.d.	n.d.	n.d.	n.d.
1987	4	68,407	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1988	3	79,020	6	8,426	3	1,165	n.d.	n.d.
1989	n.d.	n.d.	5	2,033	n.d.	n.d.	NULL	NULL
1990	10	274,936	4	2,123	3	451	n.d.	n.d.
1991	12	222,235	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1992	13	247,721	9	6,998	8	14,558	NULL	NULL
1993	8	394,896	10	12,045	5	22,492	n.d.	n.d.
1994	7	198,718	9	5,130	8	12,948	NULL	NULL
1995	8	252,684	6	6,072	6	15,149	n.d.	n.d.
1996	5	44,863	8	9,763	6	9,248	n.d.	n.d.
1997	9	97,418	6	12,556	6	6,169	n.d.	n.d.
1998	10	698,010	6	12,103	6	19,641	n.d.	n.d.

Fiscal Year	Akule		Weke (misc.)		Ta'ape		Opelu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1999	7	589,149	12	13,361	8	18,275	n.d.	n.d.
2000	9	636,089	5	6,236	5	13,654	NULL	NULL
2001	10	579,500	7	8,844	6	12,386	n.d.	n.d.
2002	4	330,385	6	4,579	3	4,978	n.d.	n.d.
2003	3	53,492	6	1,670	7	10,507	n.d.	n.d.
2004	5	92,423	7	1,747	13	11,169	3	364
2005	4	80,927	n.d.	n.d.	9	28,648	n.d.	n.d.
2006	6	44,799	n.d.	n.d.	13	22,816	NULL	NULL
2007	5	75,070	NULL	NULL	13	16,953	NULL	NULL
2008	6	53,194	n.d.	n.d.	11	19,307	3	2,512
2009	8	71,279	NULL	NULL	15	20,945	n.d.	n.d.
2010	11	86,288	n.d.	n.d.	17	15,492	3	1,811
2011	8	29,822	n.d.	n.d.	13	29,445	n.d.	n.d.
2012	9	42,285	n.d.	n.d.	12	12,186	3	1,064
2013	4	19,837	n.d.	n.d.	10	18,030	n.d.	n.d.
2014	4	18,147	NULL	NULL	14	10,728	n.d.	n.d.
2015	5	36,252	NULL	NULL	11	16,408	n.d.	n.d.
2016	10	102,076	NULL	NULL	9	19,144	NULL	NULL
2017	9	61,062	NULL	NULL	13	20,358	NULL	NULL
10-year avg.	**7**	**54,254**	**n.d.**	**n.d.**	**13**	**18,021**	**n.d.**	**n.d.**
20-year avg.	**7**	**187,237**	**4**	**4,665**	**10**	**16,423**	**n.d.**	**n.d.**

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

Table 23. HDAR MHI fiscal annual CREMUS finfish catch (lbs.) summary (1966-2017) by species and fifth gear: spear.

Fiscal Year	Uhu (misc.)		Palani		Kala		Manini	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1967	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
1968	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1969	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1970	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1971	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1972	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1973	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

1974	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1975	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	NULL
1976	6	350	4	96	NULL	NULL	4	23
1977	12	419	3	100	n.d.	n.d.	n.d.	n.d.
1978	47	8,843	5	220	n.d.	n.d.	n.d.	n.d.
1979	58	11,970	7	241	n.d.	n.d.	3	50
1980	56	12,564	25	568	7	169	19	362
1981	50	11,173	26	891	10	153	17	340
1982	45	10,491	22	885	11	241	17	397
1983	42	16,284	23	2,992	10	1,407	16	979
1984	50	15,855	28	3,014	13	161	20	563
1985	57	17,152	28	1,709	24	1,259	28	1,435
1986	70	23,967	36	2,026	14	1,167	32	1,225
1987	69	24,905	31	3,141	14	792	29	1,531
1988	68	35,479	30	3,366	16	963	30	1,595
1989	64	42,786	34	6,223	25	1,016	34	2,135
1990	50	20,253	24	2,133	12	294	27	1,292
1991	74	19,331	41	3,151	26	832	27	582
1992	67	27,060	32	2,624	22	638	35	771
1993	72	20,251	41	4,673	26	1,059	35	1,103
1994	78	31,501	44	4,665	33	2,271	43	1,661
1995	94	32,250	50	7,972	49	5,106	51	6,281
1996	102	25,995	57	7,940	46	2,925	52	3,175
1997	99	20,990	45	2,094	38	1,686	44	2,772
1998	90	25,193	51	4,035	34	2,565	47	1,873
1999	85	23,518	45	3,220	37	2,357	48	1,406
2000	88	22,984	45	4,530	39	2,083	43	2,134
2001	78	13,914	40	4,630	33	2,152	41	2,847
2002	78	14,865	39	3,327	43	3,502	39	1,128
2003	81	14,980	43	7,605	38	5,106	34	6,466
2004	63	14,265	41	7,077	30	6,915	30	4,949
2005	57	15,965	37	13,607	26	10,391	31	3,701
2006	58	16,426	37	6,952	23	7,072	39	4,235
2007	64	18,122	46	6,915	32	5,624	45	5,827
2008	65	23,266	39	9,178	26	6,347	42	5,554
2009	93	31,139	63	10,792	52	6,101	55	5,635
2010	77	43,112	49	12,165	42	7,833	42	9,714
2011	81	62,728	46	19,114	38	15,299	47	9,982
2012	79	66,193	44	21,736	45	19,742	52	11,454
2013	84	69,873	53	20,516	45	18,659	45	10,532
2014	67	51,217	38	14,558	32	10,619	38	7,024

2015	56	31,992	33	12,320	26	9,690	32	4,283
2016	42	23,749	23	10,110	21	5,368	26	5,950
2017	47	16,036	25	8,869	24	5,135	24	4,412
10-year avg.	**71**	**42,197**	**43**	**13,759**	**36**	**10,538**	**43**	**7,606**
20-year avg.	**74**	**30,253**	**43**	**9,733**	**35**	**7,460**	**41**	**5,378**

1.3.5 Catch Parameters by Gear

The top gear in this category is inshore handline, and the driver species landed are opelu and akule. The CPUE for this year type is relatively flat throughout the time series at approximately 68 lbs. per trip. In recent years, the numbers of fishers and trips have been about half the levels observed in the first 25 years of the time series. The driver species are landed more frequently by the more efficient net methods and with higher associated CPUEs.

Table 24. Time series of inshore handline, pelagic purse seine net, and lay gill net CPUE harvesting CREMUS finfish (1966-2017).

Fiscal Year	Inshore Handline				Purse Seine Net (Pelagic)				Lay Gill Net			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
1966	150	3,774	266,302	70.56	9	147	430,497	2,928.55	45	419	49,542	118.24
1967	182	4,008	309,477	77.21	8	146	553,059	3,788.08	50	458	57,619	125.81
1968	158	3,793	297,015	78.31	20	262	821,723	3,136.35	44	538	91,095	169.32
1969	188	3,978	339,863	85.44	22	265	598,758	2,259.46	73	570	84,914	148.97
1970	215	4,191	300,057	71.60	32	312	778,068	2,493.81	88	701	94,010	134.11
1971	266	4,082	269,197	65.95	14	251	619,914	2,469.78	100	708	137,975	194.88
1972	292	4,898	318,019	64.93	19	220	531,166	2,414.39	97	723	158,686	219.48
1973	300	4,009	262,107	65.38	27	249	578,496	2,323.28	122	850	167,162	196.66
1974	347	4,125	255,203	61.87	25	202	336,492	1,665.80	151	1,140	239,854	210.40
1975	344	4,498	352,409	78.35	22	215	238,058	1,107.25	144	1,230	288,651	234.68
1976	312	3,993	305,383	76.48	38	182	144,679	794.94	137	1,182	277,074	234.41
1977	299	3,340	201,757	60.41	25	138	370,673	2,686.04	170	1,481	351,439	237.30
1978	522	4,331	360,820	83.31	16	97	237,134	2,444.68	190	1,205	258,359	214.41
1979	557	3,074	363,052	118.10	27	104	198,671	1,910.30	162	705	161,428	228.98
1980	495	4,126	385,421	93.41	27	228	271,488	1,190.74	147	1,110	280,779	252.95
1981	539	5,442	371,769	68.31	25	208	104,009	500.04	140	1,345	352,970	262.43
1982	512	4,526	273,897	60.52	18	230	159,754	694.58	115	1,248	199,378	159.76
1983	550	5,628	316,215	56.19	27	241	153,022	634.95	121	1,271	279,881	220.21
1984	640	6,638	438,069	65.99	32	251	334,178	1,331.39	125	1,025	225,017	219.53
1985	593	5,655	306,035	54.12	13	56	46,551	831.27	57	638	141,943	222.48
1986	594	5,997	315,878	52.67	6	48	54,278	1,130.79	50	454	84,349	185.79
1987	567	6,230	385,860	61.94	13	36	20,258	562.72	47	486	60,314	124.10
1988	557	5,373	286,062	53.24	14	32	11,308	353.38	51	454	57,236	126.07
1989	546	4,890	279,454	57.15	26	113	263,017	2,327.58	73	595	79,365	133.39
1990	617	5,718	340,318	59.52	21	91	105,841	1,163.09	58	577	245,178	424.92

Fiscal Year	Inshore Handline				Purse Seine Net (Pelagic)				Lay Gill Net			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
1991	612	6,414	440,419	68.67	26	121	102,669	848.50	55	532	145,638	273.76
1992	663	7,115	493,187	69.32	16	73	47,720	653.70	67	700	192,317	274.74
1993	587	6,044	403,974	66.84	8	27	23,160	857.78	71	922	198,350	215.13
1994	605	6,023	389,643	64.69	12	35	29,766	850.46	67	747	174,593	233.73
1995	589	5,626	335,008	59.55	18	54	294,130	5,446.85	72	717	147,546	205.78
1996	641	6,813	466,273	68.44	14	88	276,929	3,146.92	66	747	201,023	269.11
1997	705	7,550	472,493	62.58	9	27	50,949	1,887.00	64	747	237,614	318.09
1998	706	7,630	444,827	58.30	8	35	28,328	809.37	52	712	245,845	345.29
1999	583	6,419	430,366	67.05	6	73	62,049	849.99	52	674	247,793	367.65
2000	571	6,891	424,637	61.62	7	48	105,931	2,206.90	42	680	254,315	373.99
2001	546	6,259	387,024	61.83	3	22	4,397	199.86	37	616	179,294	291.06
2002	477	5,270	302,263	57.36	NULL	NULL	NULL	0.00	37	467	92,792	198.70
2003	389	4,596	348,882	75.91	8	22	290,257	13,193.50	47	551	182,279	330.81
2004	326	4,006	285,912	71.37	12	57	291,421	5,112.65	43	488	168,519	345.33
2005	267	3,291	207,344	63.00	8	28	429,217	15,329.18	49	447	174,188	389.68
2006	266	2,733	203,102	74.31	5	23	356,478	15,499.04	38	384	110,986	289.03
2007	314	3,620	277,141	76.56	4	16	375,211	23,450.69	28	327	156,379	478.22
2008	284	3,306	226,571	68.53	6	84	262,029	3,119.39	31	287	150,939	525.92
2009	390	4,251	285,604	67.19	7	18	101,714	5,650.78	36	203	86,770	427.44
2010	382	4,487	308,256	68.70	8	22	52,804	2,400.18	39	328	145,384	443.24
2011	365	4,099	287,173	70.06	n.d.	n.d.	n.d.	n.d.	39	407	217,742	534.99
2012	336	3,788	237,462	62.69	n.d.	n.d.	n.d.	n.d.	33	398	201,600	506.53
2013	345	3,415	236,692	69.31	n.d.	n.d.	n.d.	n.d.	41	441	178,374	404.48
2014	283	2,923	197,882	67.70	n.d.	n.d.	n.d.	n.d.	34	461	186,918	405.46
2015	238	2,693	198,906	73.86	7	34	27,818	818.18	39	511	244,790	479.04
2016	210	2,522	180,318	71.50	3	15	16,974	1,131.60	37	452	231,673	512.55
2017	180	1,847	115,394	62.48	3	21	39,501	1,881.00	27	327	184,690	564.80

Fiscal Year	Inshore Handline				Purse Seine Net (Pelagic)				Lay Gill Net			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
10-year avg.	316	3,519	244,043	69.35	5	25	102,219	4,088.76	36	383	180,400	471.02
20-year avg.	400	4,492	297,374	66.20	6	31	138,971	4,482.94	41	480	184,881	385.17

Table 25. Time series of seine net and spear CPUE harvesting CREMUS finfish (1966-2017).

Fiscal Year	Seine Net				Spear			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
1966	5	31	18,394	593.35	NULL	NULL	NULL	0.00
1967	4	91	74,956	823.69	n.d.	n.d.	n.d.	n.d.
1968	6	83	30,244	364.39	NULL	NULL	NULL	0.00
1969	7	119	89,370	751.01	NULL	NULL	NULL	0.00
1970	5	81	36,905	455.62	NULL	NULL	NULL	0.00
1971	3	74	29,123	393.55	NULL	NULL	NULL	0.00
1972	3	64	6,789	106.08	NULL	NULL	NULL	0.00
1973	4	35	20,873	596.37	n.d.	n.d.	n.d.	n.d.
1974	4	32	19,948	623.38	NULL	NULL	NULL	0.00
1975	3	4	5,246	1,311.50	n.d.	n.d.	n.d.	n.d.
1976	3	36	358,799	9,966.64	15	39	1,287	33.00
1977	11	65	89,655	1,379.31	23	51	1,319	25.86
1978	11	97	63,475	654.38	70	318	16,631	52.30
1979	30	162	91,355	563.92	74	327	19,001	58.11
1980	13	52	37,893	728.71	78	394	26,011	66.02
1981	10	54	15,921	294.83	72	552	28,336	51.33
1982	18	116	82,967	715.23	57	495	27,562	55.68
1983	21	116	290,269	2,502.32	62	455	34,102	74.95
1984	14	75	62,692	835.89	71	491	30,171	61.45
1985	8	21	15,389	732.81	82	800	45,158	56.45

Fiscal Year	Seine Net				Spear			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
1986	6	64	37,930	592.66	90	716	48,877	68.26
1987	6	110	112,255	1,020.50	92	770	53,505	69.49
1988	11	101	100,070	990.79	92	833	69,271	83.16
1989	9	63	35,218	559.02	92	792	78,910	99.63
1990	15	118	283,108	2,399.22	82	628	44,447	70.78
1991	13	94	240,900	2,562.77	99	749	47,338	63.20
1992	20	186	298,547	1,605.09	96	895	54,082	60.43
1993	20	277	464,809	1,678.01	96	751	49,072	65.34
1994	15	109	238,403	2,187.18	115	875	61,625	70.43
1995	14	129	300,961	2,333.03	132	1,094	75,764	69.25
1996	15	162	99,743	615.70	143	1,047	58,782	56.14
1997	17	146	139,146	953.05	140	802	40,931	51.04
1998	17	198	755,425	3,815.28	128	912	50,731	55.63
1999	20	188	643,390	3,422.29	119	861	47,853	55.58
2000	13	130	667,234	5,132.57	115	822	50,685	61.66
2001	18	116	613,925	5,292.46	110	673	38,805	57.66
2002	10	65	361,127	5,555.80	108	637	35,665	55.99
2003	15	166	138,804	836.17	105	672	47,636	70.89
2004	23	229	195,862	855.29	80	696	47,247	67.88
2005	17	238	200,324	841.70	78	752	57,827	76.90
2006	21	219	151,261	690.69	82	729	51,233	70.28
2007	24	215	187,849	873.72	96	882	57,313	64.98
2008	23	209	144,626	691.99	81	989	64,845	65.57
2009	28	276	164,758	596.95	128	1,332	82,441	61.89
2010	33	335	190,900	569.85	110	1,505	119,727	79.55
2011	23	294	149,084	507.09	109	1,522	169,297	111.23
2012	24	177	109,493	618.60	109	1,458	185,632	127.32
2013	18	173	98,394	568.75	114	1,417	187,608	132.40

Fiscal Year	Seine Net				Spear			
	No. License	No. Trips	Lbs. Caught	CPUE	No. License	No. Trips	Lbs. Caught	CPUE
2014	23	193	105,467	546.46	101	1,026	123,958	120.82
2015	21	165	117,859	714.30	86	966	86,790	89.84
2016	20	178	167,564	941.37	63	675	66,797	98.96
2017	19	191	134,735	705.42	65	666	53,194	79.87
10-year avg.	**24**	**228**	**146,678**	**643.32**	**100**	**1,178**	**114,565**	**97.25**
20-year avg.	**21**	**199**	**266,702**	**1,340.21**	**103**	**967**	**80,713**	**83.47**

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

1.4 CRUSTACEAN

1.4.1 Fishery Descriptions

This species group is comprised of the *Heterocarpus* deep water shrimps (*H. laevigatus* and *H. ensifer*), spiny lobsters (*Panulirus marginatus* and *P. Penicillatus*), slipper lobsters (*Scyllaridae haanii* and *S. squammosus*), kona crab (*Ranina ranina*), kuahonu crab (*Portunus Sanguinolentus*), Hawaiian crab (*Podophthalmus vigil*), opaelolo (*Penaeus marginatus*), and ‘a‘ama crab (*Grapsus tenuicrustatus*). The main gear types used are shrimp traps, loop nets, miscellaneous traps, and crab traps.

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 Online Fishing Report system (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.

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

Table 26. Annual fishing parameters for the 2017 fishing year in the MHI crustacean fishery compared with short-term (10-year) and long-term (20-year) averages.

Fishery	Parameters	2017 Values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Long-Term Avg. (20-year)
Crustacean	No. License	38	↓ 45.7%	↓ 60.0%
	Trips	473	↓ 35.0%	↓ 33.9%
	No. Caught	75,551	↓ 62.4%	↓ 35.9%
	Lbs. Caught	30,608	↓ 51.3%	↓ 54.3%

1.4.2.2 Species Summary

Table 27. Annual fishing parameters for the 2017 fishing year in the MHI crustacean fishery compared with short-term (10-year) and long-term (20-year) averages.

Methods	Fishery indicators	2017 values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Short-Term Avg. (20-year)
Shrimp trap	*H. laevigatus*	N/A	N/A	N/A
	No. Lic.	N/A	N/A	N/A

	No. Trips	N/A	N/A	N/A
	Lbs. Caught	N/A	N/A	N/A
	CPUE	N/A	N/A	N/A
Loop net	Kona crab	1,691 lbs.	↓ 77.1%	↓ 85.9%
	No. Lic.	17	↓ 50.0%	↓ 66.0%
	No. Trips	36	↓ 72.9%	↓ 78.4%
	Lbs. Caught	1,691 lbs.	↓ 77.2%	↓ 86.0%
	CPUE	46.97 lbs./trip	↓ 15.6%	↓ 34.9%
Hand grab (lobster)	Green spiny	3,575 lbs.	↓ 54.6%	N/A
	Red spiny	3,713 lbs.	↓ 60.1%	N/A
	No. Lic.	12	↓ 36.8%	↓ 55.6%
	No. Trips	156	↓ 36.3%	↓ 34.2%
	Lbs. Caught	4,710 lbs.	↓ 53.0%	↓ 48.0%
	CPUE	30.19 lbs./trip	↓ 26.2%	↓ 21.0%

1.4.3 Time Series Statistics

1.4.3.1 Commercial Fishing Parameters

Table 28. Time series of commercial fishermen reports for the crustacean fishery (1966-2017).

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1966	64	805	234	12,042	33,264
1967	74	759	259	3,814	38,359
1968	56	592	205	2,313	40,873
1969	84	817	268	4,580	56,873
1970	75	886	269	13,514	82,730
1971	94	1,248	352	67,103	104,014
1972	92	1,070	319	3,479	119,988
1973	77	942	293	2,485	107,373
1974	113	911	321	14,124	80,283
1975	109	1,123	320	10,047	89,689
1976	125	1,041	337	9,784	74,056
1977	125	1,199	381	10,999	64,335
1978	138	781	403	10,678	68,289
1979	115	472	309	7,596	42,366
1980	111	487	257	5,216	24,689
1981	117	631	290	6,480	27,641
1982	111	740	325	4,370	30,683
1983	121	865	354	12,732	38,359
1984	170	1,251	436	12,867	238,819
1985	160	1,357	440	14,086	110,456

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1986	160	1,000	431	9,078	53,374
1987	173	1,048	422	12,804	51,870
1988	124	806	300	7,807	48,713
1989	106	596	249	3,984	74,013
1990	122	747	278	7,526	377,734
1991	132	845	324	10,311	123,992
1992	148	935	339	13,526	77,038
1993	129	831	319	7,729	86,093
1994	130	821	323	6,627	100,993
1995	140	856	383	6,715	117,203
1996	172	1,016	405	8,980	119,882
1997	159	785	365	11,909	79,349
1998	157	945	388	13,987	80,900
1999	157	802	365	14,865	242,736
2000	149	782	345	18,691	53,546
2001	128	615	280	14,616	34,803
2002	113	576	275	14,717	32,919
2003	96	495	221	48,737	35,703
2004	85	499	195	49,743	36,308
2005	82	737	188	75,462	97,915
2006	74	789	193	83,508	146,245
2007	59	577	174	92,091	41,580
2008	67	727	200	159,459	67,074
2009	83	761	212	160,505	59,563
2010	78	872	235	169,993	70,786
2011	93	766	246	141,811	60,222
2012	73	667	212	145,928	40,785
2013	65	758	214	253,962	69,715
2014	66	870	206	534,365	100,880
2015	59	677	176	205,650	65,574
2016	56	613	189	147,321	53,563
2017	38	473	139	75,551	30,608
10-year avg.	**70**	**728**	**206**	**201,099**	**62,897**
20-year avg.	**95**	**715**	**244**	**117,861**	**73,470**

1.4.4 Top 4 Species per Gear Type

1.4.4.1 Shrimp Trap

The shrimp trap gear code was established in 1985. Prior to 1985, all trap activities were reported under miscellaneous traps. The principal species taken by shrimp traps/pots are the deep water

Heterocarpus shrimp. There are only a handful of resident fishers in Hawaii who actively fish for this species. The deep water *Heterocarpus* shrimp fishery pulses every five to seven years; large vessels from the mainland return to the islands to harvest the shrimp, and then land it in the State for export to external markets.

Table 29. HDAR MHI fiscal annual crustacean catch (lbs.) summary (1987-2017) by species and top gear: shrimp trap.

Fiscal Year	Laevigatus		Ensifer		Opaelolo	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	NULL	NULL	NULL	NULL	NULL	NULL
1967	NULL	NULL	NULL	NULL	NULL	NULL
1968	NULL	NULL	NULL	NULL	NULL	NULL
1969	NULL	NULL	NULL	NULL	NULL	NULL
1970	NULL	NULL	NULL	NULL	NULL	NULL
1971	NULL	NULL	NULL	NULL	NULL	NULL
1972	NULL	NULL	NULL	NULL	NULL	NULL
1973	NULL	NULL	NULL	NULL	NULL	NULL
1974	NULL	NULL	NULL	NULL	NULL	NULL
1975	NULL	NULL	NULL	NULL	NULL	NULL
1976	NULL	NULL	NULL	NULL	NULL	NULL
1977	NULL	NULL	NULL	NULL	NULL	NULL
1978	NULL	NULL	NULL	NULL	NULL	NULL
1979	NULL	NULL	NULL	NULL	NULL	NULL
1980	NULL	NULL	NULL	NULL	NULL	NULL
1981	NULL	NULL	NULL	NULL	NULL	NULL
1982	NULL	NULL	NULL	NULL	NULL	NULL
1983	NULL	NULL	NULL	NULL	NULL	NULL
1984	NULL	NULL	NULL	NULL	NULL	NULL
1985	NULL	NULL	NULL	NULL	NULL	NULL
1986	NULL	NULL	NULL	NULL	NULL	NULL
1987	3	1,796	n.d.	n.d.	n.d.	n.d.
1988	n.d.	n.d.	3	1568	NULL	NULL
1989	n.d.	n.d.	n.d.	n.d.	NULL	NULL
1990	5	341,780	n.d.	n.d.	NULL	NULL
1991	n.d.	n.d.	NULL	NULL	NULL	NULL
1992	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1993	n.d.	n.d.	NULL	NULL	NULL	NULL
1994	4	47,737	n.d.	n.d.	NULL	NULL
1995	6	69,962	n.d.	n.d.	n.d.	n.d.
1996	4	67,077	n.d.	n.d.	n.d.	n.d.
1997	8	32,564	n.d.	n.d.	n.d.	n.d.

Fiscal Year	Laevigatus		Ensifer		Opaelolo	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1998	7	21,157	n.d.	n.d.	n.d.	n.d.
1999	5	185,139	n.d.	n.d.	NULL	NULL
2000	3	11,770	n.d.	n.d.	NULL	NULL
2001	4	6,307	n.d.	n.d.	n.d.	n.d.
2002	n.d.	n.d.	NULL	NULL	NULL	NULL
2003	3	4,284	n.d.	n.d.	NULL	NULL
2004	n.d.	n.d.	NULL	NULL	NULL	NULL
2005	4	51,996	n.d.	n.d.	NULL	NULL
2006	5	99,718	n.d.	n.d.	NULL	NULL
2007	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2008	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2009	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2010	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2011	n.d.	n.d.	n.d.	n.d.	NULL	NULL
2012	4	6,854	n.d.	n.d.	NULL	NULL
2013	5	12,759	n.d.	n.d.	NULL	NULL
2014	10	47,764	5	927	NULL	NULL
2015	7	27,163	3	21	NULL	NULL
2016	5	27,009	n.d.	n.d.	NULL	NULL
2017	n.d.	n.d.	n.d.	n.d.	NULL	NULL
10-year avg.	**4**	**13,846**	**n.d.**	**n.d.**	**NULL**	**NULL**
20-year avg.	**4**	**27,964**	**n.d.**	**n.d.**	**n.d.**	**n.d.**

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

1.4.4.2 Loop Net

The driver species for the loop net gear is the kona crab with the kuahonu (i.e. white) crab comprising a large portion of the bycatch. The levels of fishing effort and landings have gradually declined since 2000. The State has established and amended several regulations on the taking and sale of kona crab. In addition to long-standing restrictions for minimum size, berried females, and season closure, additional prohibitions on the harvesting of females hurt fishing effort and may have discouraged further participation. Another factor that impacted the decline in kona crab landings was the retirement of a long-time highline fisher several years ago.

Table 30. HDAR MHI fiscal annual crustacean catch (lbs.) summary (1987-2017) by species and second gear: loop net.

Fiscal Year	Kona Crab		Kuahonu Crab	
	No. License	Lbs. Caught	No. License	Lbs. Caught

Fiscal Year	Kona Crab		Kuahonu Crab	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	21	10029	NULL	NULL
1967	30	17,444	NULL	NULL
1968	25	26,419	NULL	NULL
1969	28	35,939	NULL	NULL
1970	29	35,033	NULL	NULL
1971	38	42,977	NULL	NULL
1972	40	69,328	NULL	NULL
1973	32	62,455	NULL	NULL
1974	49	39,121	NULL	NULL
1975	58	23,996	NULL	NULL
1976	50	23,195	n.d.	n.d.
1977	33	15,966	NULL	NULL
1978	60	28,582	NULL	NULL
1979	51	24,674	NULL	NULL
1980	39	8,162	NULL	NULL
1981	47	12,102	NULL	NULL
1982	48	8,291	NULL	NULL
1983	48	9,009	NULL	NULL
1984	58	12,904	NULL	NULL
1985	71	20,846	NULL	NULL
1986	80	27,200	NULL	NULL
1987	62	16,310	NULL	NULL
1988	47	12,475	NULL	NULL
1989	32	11,790	4	668
1990	32	16,118	NULL	NULL
1991	44	22,789	NULL	NULL
1992	71	34,291	NULL	NULL
1993	66	25,305	n.d.	n.d.
1994	70	23,770	NULL	NULL
1995	77	22,763	NULL	NULL
1996	88	30,581	NULL	NULL
1997	86	28,893	n.d.	n.d.
1998	82	28,611	n.d.	n.d.
1999	90	25,417	n.d.	n.d.
2000	84	16,908	n.d.	n.d.
2001	61	10,035	n.d.	n.d.
2002	64	11,372	n.d.	n.d.
2003	51	11,755	3	17
2004	49	12,685	n.d.	n.d.

Fiscal Year	Kona Crab		Kuahonu Crab	
	No. License	Lbs. Caught	No. License	Lbs. Caught
2005	51	11,750	n.d.	n.d.
2006	38	9,143	3	58
2007	33	5,653	n.d.	n.d.
2008	35	13,136	3	14
2009	43	7,519	3	15
2010	39	11,449	3	12
2011	49	10,609	n.d.	n.d.
2012	41	8,149	n.d.	n.d.
2013	28	9,551	n.d.	n.d.
2014	29	2,999	3	19
2015	24	2,293	n.d.	n.d.
2016	23	2,512	n.d.	n.d.
2017	17	1,690	n.d.	n.d.
10-year avg.	**34**	**7,389**	**n.d.**	**n.d.**
20-year avg.	**50**	**12,023**	**n.d.**	**n.d.**

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

1.4.4.3 Crab Trap

The gear code for crab traps was established in 1985. Prior to 1985 all trap activities were reported under the code for miscellaneous traps. The driver species for this gear is the kuahonu crab. Throughout the time series, there has been a small group of fishers, numbering no more than eight in a year, participating in this fishery. There is a market demand for kuahonu crab and the landings have been trending upwards over the past eight years (with the exception of 2015, which has confidential data that remains undisclosed).

Table 31. HDAR MHI fiscal annual crustacean catch (lbs.) summary (1987-2017) by species and third gear: crab trap.

Fiscal Year	Kuahonu Crab		Kona Crab		Samoan Crab		Spiny Lobster	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	3	5,399	NULL	NULL	n.d.	n.d.	12	2,683
1967	5	4,070	NULL	NULL	NULL	NULL	9	2,180
1968	4	2,757	NULL	NULL	n.d.	n.d.	9	1,714
1969	8	2,488	n.d.	n.d.	4	305	14	4,142
1970	7	19,012	n.d.	n.d.	n.d.	n.d.	8	1,983
1971	11	42,507	n.d.	n.d.	NULL	NULL	11	1,878
1972	8	39,091	n.d.	n.d.	n.d.	n.d.	12	2,886
1973	8	34,095	NULL	NULL	n.d.	n.d.	10	3,945

1974	11	28,858	n.d.	n.d.	NULL	NULL	14	3,969
1975	11	52,730	n.d.	n.d.	NULL	NULL	13	2,599
1976	11	29,457	n.d.	n.d.	NULL	NULL	10	1,619
1977	10	10,024	n.d.	n.d.	n.d.	n.d.	14	4,382
1978	7	17,015	n.d.	n.d.	n.d.	n.d.	14	5,383
1979	3	3,409	NULL	NULL	NULL	NULL	12	2,139
1980	5	1,590	3	2099	n.d.	n.d.	15	4,303
1981	5	2,054	NULL	NULL	n.d.	n.d.	11	2,372
1982	5	2,693	n.d.	n.d.	NULL	NULL	12	4,937
1983	3	2,832	n.d.	n.d.	NULL	NULL	16	4,639
1984	5	3,167	n.d.	n.d.	NULL	NULL	19	11,279
1985	6	7,437	n.d.	n.d.	n.d.	n.d.	22	9,347
1986	n.d.	n.d.	NULL	NULL	NULL	NULL	3	465
1987	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3	179
1988	n.d.	n.d.	n.d.	n.d.	NULL	NULL	n.d.	n.d.
1989	NULL	NULL	NULL	NULL	NULL	NULL	n.d.	n.d.
1990	NULL	NULL	NULL	NULL	NULL	NULL	n.d.	n.d.
1991	n.d.	n.d.	NULL	NULL	n.d.	n.d.	n.d.	n.d.
1992	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	NULL
1993	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1994	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
1995	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
1996	n.d.	n.d.	n.d.	n.d.	NULL	NULL	NULL	NULL
1997	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
1998	n.d.	n.d.	NULL	NULL	n.d.	n.d.	3	95
1999	n.d.	n.d.	NULL	NULL	NULL	NULL	3	20
2000	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2001	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2002	n.d.	n.d.	NULL	NULL	NULL	NULL	n.d.	n.d.
2003	n.d.	n.d.	NULL	NULL	n.d.	n.d.	NULL	NULL
2004	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2005	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2006	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2007	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2008	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2009	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2010	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2011	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2012	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2013	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2014	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

2015	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2016	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2017	NULL	NULL	NULL	NULL	4	1138	NULL	NULL

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

1.4.4.4 Hand grab for Crustaceans

DLNR-DAR standardized the gear/method definitions for hand grab in October 2002. For the harvesting of crustaceans/lobsters by hand, the "diving" gear code had been used. It is defined as "Fishing while swimming free dive (skin diving) or swimming with the assistance of compressed gases (SCUBA, rebreathers, etc.). Examples are lobster or namako diving. Does not include diving with a spear (see spearfishing), a net (see various nets), or for limu or opihi (see handpicking). Typical species: various marine species."

Table 32. HDAR MHI fiscal annual crustacean catch (lbs.) summary (1987-2017) by species and fourth gear: hand grab.

Fiscal Year	Green Spiny Lobster		Spiny Lobster		Red Spiny Lobster		A'ama / Black Crab		Slipper Lobster	
	No. Lic.	Lbs. Caught	No. Lic.	Lbs. Caught	No. Lic.	Lbs. Caught	No. Lic.	Lbs. Caught	No. Lic.	Lbs. Caught
1966	NULL	NULL	4	177	NULL	NULL	NULL	NULL	NULL	NULL
1967	NULL	NULL	3	179	NULL	NULL	NULL	NULL	NULL	NULL
1968	NULL	NULL	n.d.	n.d.	NULL	NULL	NULL	NULL	NULL	NULL
1969	NULL	NULL	5	261	NULL	NULL	NULL	NULL	NULL	NULL
1970	NULL	NULL	7	1,062	NULL	NULL	NULL	NULL	n.d.	n.d.
1971	NULL	NULL	7	264	NULL	NULL	NULL	NULL	n.d.	n.d.
1972	NULL	NULL	10	505	NULL	NULL	NULL	NULL	NULL	NULL
1973	NULL	NULL	7	267	NULL	NULL	NULL	NULL	NULL	NULL
1974	NULL	NULL	18	767	NULL	NULL	NULL	NULL	n.d.	n.d.
1975	NULL	NULL	6	252	NULL	NULL	NULL	NULL	NULL	NULL
1976	NULL	NULL	7	617	NULL	NULL	NULL	NULL	NULL	NULL
1977	NULL	NULL	11	657	NULL	NULL	NULL	NULL	n.d.	n.d.
1978	NULL	NULL	19	630	NULL	NULL	NULL	NULL	3	111
1979	NULL	NULL	19	764	NULL	NULL	NULL	NULL	4	73
1980	NULL	NULL	14	708	NULL	NULL	NULL	NULL	n.d.	n.d.
1981	NULL	NULL	11	160	NULL	NULL	NULL	NULL	NULL	NULL
1982	NULL	NULL	4	264	NULL	NULL	NULL	NULL	NULL	NULL
1983	NULL	NULL	6	484	NULL	NULL	NULL	NULL	NULL	NULL
1984	NULL	NULL	7	344	NULL	NULL	NULL	NULL	NULL	NULL
1985	NULL	NULL	11	487	NULL	NULL	NULL	NULL	NULL	NULL
1986	NULL	NULL	25	2,877	NULL	NULL	n.d.	n.d.	n.d.	n.d.
1987	NULL	NULL	35	3,208	NULL	NULL	9	385	3	54
1988	NULL	NULL	33	4,369	NULL	NULL	8	840	3	66

1989	NULL	NULL	24	3,084	NULL	NULL	5	226	n.d.	n.d.
1990	NULL	NULL	36	3,997	NULL	NULL	NULL	NULL	NULL	NULL
1991	NULL	NULL	39	2,904	NULL	NULL	NULL	NULL	6	31
1992	NULL	NULL	33	3,543	NULL	NULL	NULL	NULL	n.d.	n.d.
1993	NULL	NULL	23	1,268	NULL	NULL	NULL	NULL	n.d.	n.d.
1994	NULL	NULL	24	799	NULL	NULL	NULL	NULL	n.d.	n.d.
1995	NULL	NULL	27	2,359	NULL	NULL	NULL	NULL	3	26
1996	NULL	NULL	51	6,504	NULL	NULL	NULL	NULL	5	81
1997	NULL	NULL	39	5,119	NULL	NULL	NULL	NULL	5	58
1998	NULL	NULL	37	8,878	NULL	NULL	NULL	NULL	3	25
1999	NULL	NULL	39	6,596	NULL	NULL	NULL	NULL	n.d.	n.d.
2000	NULL	NULL	44	8,480	NULL	NULL	NULL	NULL	8	83
2001	NULL	NULL	41	7,212	NULL	NULL	NULL	NULL	n.d.	n.d.
2002	NULL	NULL	36	9,998	NULL	NULL	NULL	NULL	6	38
2003	12	4667	15	1,036	24	5396	n.d.	n.d.	n.d.	n.d.
2004	15	4577	n.d.	n.d.	24	6782	3	146	NULL	NULL
2005	14	10023	4	167	19	10263	n.d.	n.d.	NULL	NULL
2006	17	9381	5	387	22	9647	n.d.	n.d.	n.d.	n.d.
2007	12	8645	n.d.	n.d.	15	8990	n.d.	n.d.	n.d.	n.d.
2008	15	7657	n.d.	n.d.	15	7834	NULL	NULL	n.d.	n.d.
2009	18	10695	n.d.	n.d.	21	11149	n.d.	n.d.	n.d.	n.d.
2010	18	10302	n.d.	n.d.	21	14088	n.d.	n.d.	n.d.	n.d.
2011	21	9702	NULL	NULL	26	11479	n.d.	n.d.	NULL	NULL
2012	15	8176	NULL	NULL	20	10350	NULL	NULL	n.d.	n.d.
2013	16	8843	NULL	NULL	18	10429	NULL	NULL	NULL	NULL
2014	10	6594	n.d.	n.d.	12	9329	NULL	NULL	n.d.	n.d.
2015	12	7983	NULL	NULL	15	8971	n.d.	n.d.	NULL	NULL
2016	8	4739	NULL	NULL	9	5250	n.d.	n.d.	NULL	NULL
2017	8	3575	NULL	NULL	9	3713	n.d.	n.d.	n.d.	n.d.

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

1.4.5 Catch Parameters by Gear

Table 33. Time series of CPUE by dominant fishing methods from crustaceans (1966-2017).

Fiscal Year	Shrimp Trap				Kona Crab Net (Loop)				Hand/Grab				Crab Trap			
	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE
1966	NULL	NULL	NULL	0	21	178	10,029	56.34	4	8	177	22.13	n.d.	n.d.	n.d.	n.d.
1967	NULL	NULL	NULL	0	30	185	17,444	94.29	3	4	179	44.75	6	76	2,758	36.29
1968	NULL	NULL	NULL	0	25	167	26,419	158.2	n.d.	n.d.	n.d.	n.d.	4	96	2,624	27.33
1969	NULL	NULL	NULL	0	28	232	35,939	154.91	5	16	261	16.31	11	132	4,095	31.02
1970	NULL	NULL	NULL	0	29	195	35,033	179.66	7	31	1,075	34.68	11	73	2,384	32.66
1971	NULL	NULL	NULL	0	38	241	42,977	178.33	7	16	265	16.56	6	133	3,211	24.14
1972	NULL	NULL	NULL	0	40	259	69,328	267.68	10	35	505	14.43	9	120	3,560	29.67
1973	NULL	NULL	NULL	0	32	230	62,455	271.54	7	13	267	20.54	9	66	1,354	20.52
1974	NULL	NULL	NULL	0	49	199	39,121	196.59	18	49	772	15.76	7	83	2,130	25.66
1975	NULL	NULL	NULL	0	58	233	23,996	102.99	6	12	252	21	11	141	2,694	19.11
1976	NULL	NULL	NULL	0	50	205	23,256	113.44	7	22	617	28.05	30	159	5,047	31.74
1977	NULL	NULL	NULL	0	33	133	15,966	120.05	12	33	723	21.91	43	383	16,237	42.39
1978	NULL	NULL	NULL	0	60	227	28,582	125.91	22	39	741	19	16	120	3,799	31.66
1979	NULL	NULL	NULL	0	51	188	24,674	131.24	20	34	837	24.62	21	102	6,396	62.71
1980	NULL	NULL	NULL	0	40	101	8,192	81.11	15	21	732	34.86	21	98	2,779	28.36
1981	NULL	NULL	NULL	0	47	143	12,102	84.63	11	20	160	8	15	73	2,419	33.14
1982	NULL	NULL	NULL	0	48	163	8,291	50.87	4	7	264	37.71	16	54	1,534	28.41
1983	NULL	NULL	NULL	0	48	148	9,305	62.87	6	18	496	27.56	22	93	3,730	40.11
1984	NULL	NULL	NULL	0	58	178	12,904	72.49	7	17	344	20.24	29	81	2,182	26.94
1985	NULL	NULL	NULL	0	71	309	20,846	67.46	11	19	487	25.63	16	69	1,149	16.65
1986	NULL	NULL	NULL	0	80	302	27,200	90.07	29	122	2,976	24.39	13	56	755	13.48
1987	5	26	3,481	133.88	62	158	16,310	103.23	48	219	3,774	17.23	9	20	358	17.9
1988	3	44	12,934	293.95	47	179	12,475	69.69	41	247	5,518	22.34	6	7	352	50.29
1989	n.d.	n.d.	n.d.	n.d.	33	140	12,458	88.99	29	160	3,338	20.86	7	14	312	22.29

 Fishery Performance

Fiscal Year	Shrimp Trap				Kona Crab Net (Loop)				Hand/Grab				Crab Trap			
	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE
1990	5	87	343,102	3943.7	32	130	16,118	123.98	36	142	3,997	28.15	18	78	1,233	15.81
1991	n.d.	n.d.	n.d.	n.d.	44	161	22,789	141.55	40	179	2,935	16.4	12	77	1,785	23.18
1992	n.d.	n.d.	n.d.	n.d.	71	316	34,291	108.52	33	141	3,556	25.22	11	23	524	22.78
1993	n.d.	n.d.	n.d.	n.d.	66	309	25,306	81.9	23	80	1,277	15.96	12	14	269	19.21
1994	4	75	49,505	660.07	70	245	23,770	97.02	25	68	824	12.12	9	31	446	14.39
1995	7	103	74,697	725.21	77	296	22,763	76.9	28	148	2,415	16.32	7	26	412	15.85
1996	5	190	70,386	370.45	88	329	30,581	92.95	52	289	6,586	22.79	5	13	114	8.77
1997	9	99	34,009	343.53	86	278	28,895	103.94	39	200	5,184	25.92	n.d.	n.d.	n.d.	n.d.
1998	8	82	21,537	262.65	82	307	28,632	93.26	38	272	8,903	32.73	4	7	173	24.71
1999	5	111	186,400	1,679.2	90	258	25,425	98.55	39	186	6,604	35.51	5	9	50	5.56
2000	3	72	11,798	163.86	84	195	16,914	86.74	45	264	8,573	32.47	n.d.	n.d.	n.d.	n.d.
2001	6	64	6,436	100.56	61	151	10,067	66.67	43	193	7,273	37.68	n.d.	n.d.	n.d.	n.d.
2002	n.d.	n.d.	n.d.	n.d.	64	179	11,382	63.59	37	194	10,036	51.73	5	12	53	4.42
2003	3	50	4,748	94.96	51	165	11,772	71.35	33	175	6,600	37.71	3	4	65	16.25
2004	n.d.	n.d.	n.d.	n.d.	49	158	12,690	80.32	28	234	7,001	29.92	n.d.	n.d.	n.d.	n.d.
2005	4	67	54,379	811.63	51	170	11,815	69.5	24	300	10,512	35.04	NULL		NULL	0
2006	5	163	103,857	637.16	38	160	9,201	57.51	23	274	10,095	36.84	n.d.	n.d.	n.d.	n.d.
2007	n.d.	n.d.	n.d.	n.d.	33	133	5,657	42.53	16	275	9,128	33.19	3	20	177	8.85
2008	n.d.	n.d.	n.d.	n.d.	35	221	13,150	59.5	16	191	8,354	43.74	9	94	1,356	14.43
2009	n.d.	n.d.	n.d.	n.d.	43	168	7,534	44.85	24	271	11,329	41.8	5	109	1,475	13.53
2010	n.d.	n.d.	n.d.	n.d.	39	209	11,461	54.84	24	361	14,422	39.95	4	60	1,756	29.27
2011	n.d.	n.d.	n.d.	n.d.	49	190	10,622	55.91	30	268	11,539	43.06	5	82	1,300	15.85
2012	4	95	7,140	75.16	41	128	8,154	63.7	21	267	10,421	39.03	5	57	906	15.89
2013	5	150	12,972	86.48	28	106	9,554	90.13	19	233	10,452	44.86	5	61	1,309	21.46
2014	10	316	48,691	154.09	29	59	3,017	51.14	14	234	9,350	39.96	n.d.	n.d.	n.d.	n.d.
2015	7	228	27,184	119.23	24	64	2,319	36.23	18	191	9,230	48.32	5	31	493	15.9
2016	5	171	27,041	158.13	23	49	2,525	51.53	12	158	5,499	34.8	7	36	811	22.53

 Fishery Performance

Fiscal Year	Shrimp Trap				Kona Crab Net (Loop)				Hand/Grab				Crab Trap			
	No. Lic.	**No. Trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. Trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. Trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. Trips**	**Lbs. Caught**	**CPUE**
2017	n.d.	n.d.	n.d.	n.d.	17	36	1,691	46.97	12	156	4,710	30.19	5	52	1,140	21.92
10-year avg.	**4**	**116**	**14,804**	**127.62**	**34**	**133**	**7,402**	**55.65**	**19**	**245**	**10,025**	**40.92**	**5**	**58**	**1,016**	**17.52**
20-year avg.	**4**	**97**	**28,955**	**298.51**	**50**	**167**	**12,040**	**72.1**	**27**	**237**	**9,052**	**38.19**	**4**	**33**	**561**	**17**

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

1.5 MOLLUSK AND LIMU

1.5.1 Fishery Descriptions

This species category is comprised of algae including miscellaneous *Gracilaria* spp., limu kohu (*Asparagopsis taxiformis*), limu manauea (*Gracilaria coronopifolia*), ogo (*G. parvispora*), limu wawaeiole (*U. fasciata*), mollusks including clam (*Tapes phililippinarum*), he'e (*Octopus cyanea*), he'e pu loa (*O. ornatus*), other octopus (*Octopus spp.*), hihiwai (*Theodoxus* spp.), opihi 'alina (yellowfoot, *Cellana sandwicensis*), opihi makaiauli (black foot, *C. exarata*), opihi (*Cellana* spp.), and pupu (top shell).

The top gear types to harvest these species are hand pick, spear, and inshore handline.

1.5.2 Dashboard Statistics

The collection of commercial mollusk and limu 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). The mollusk and limu landings are reported by commercial fishers in the Monthly Fishing Report or the Net, Trap, Dive Activity Report.

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 data monitoring associates are to enter the paper Monthly Fishing Report information within four weeks, and the Net, Trap, Dive Activity Report within two business days.

1.5.2.1 Historical Summary

Table 34. Annual fishing parameters for the 2017 fishing year in the MHI mollusk and limu fishery compared with short-term (10-year) and long-term (20-year) averages.

Fishery	Parameters	2017 Values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Short-Term Avg. (20-year)
Mollusk and Limu	No. License	75	↓ 42.3%	↓ 50.3%
	Trips	791	↓ 53.1%	↓ 58.5%
	No. Caught	65,318	↑ 178%	↑ 295%
	Lbs. Caught	28,980	↓ 51.1%	↓43.8%

1.5.2.2 Species Summary

Table 35. Annual fishing parameters for the 2017 fishing year in the MHI mollusk and limu fishery compared with short-term (10-year) and long-term (20-year) averages.

Methods	Fishery indicators	2017 values	2017 Comparative Trends	
			Short-Term Avg. (10-year)	Short-Term Avg. (20-year)
Hand pick	Opihi	1,659 lbs.	↓ 39.7%	↓ 68.4%
	Opihi'alina	7,380 lbs.	↓ 48.7%	↓ 41.4%

	Wawaaeiole	N/A	N/A	N/A
	Limu kohu	4,887 lbs.	↑ 21.2%	↑ 52.0%
	No. Lic.	22	↓ 51.1%	↓ 60.0%
	No. Trips	301	↓ 56.6%	↓ 67.0%
	Lbs. Caught	13,938 lbs.	↓ 50.3%	↓ 42.9%
	CPUE	46.31 lbs./trip	↑ 14.6%	↑ 72.4%
Spear	Octopus (misc.)	207 lbs.	↓ 7.17%	↓ 96.5%
	He'e day tako	11,672 lbs.	↓ 52.7%	N/A
	No. Lic.	37	↓ 41.3%	↓ 45.6%
	No. Trips	382	↓ 48.2%	↓ 47.7%
	Lbs. Caught	11,879 lbs.	↓ 52.3%	↓ 41.1%
	CPUE	31.1 lbs./trip	↓ 7.77%	↑ 12.7%
Inshore handline	Octopus (misc.)	N/A	N/A	N/A
	He'e day tako	2,505 lbs.	↓ 51.9%	↓ 50.6%
	No. Lic.	14	↓ 33.3%	↓ 50.0%
	No. Trips	51	↓ 72.6%	↓ 76.3%
	Lbs. Caught	2,505 lbs.	↓ 52.8%	↓ 57.4%
	CPUE	49.12 lbs./trip	↑ 72.1%	↑ 79.5%

1.5.3 Time Series Statistics

1.5.3.1 Commercial Fishing Parameters

Table 36. Time series of commercial fishermen reports for the mollusk and limu fishery (1966-2017).

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1966	43	435	195	2,070	23,044
1967	75	996	293	2,764	44,221
1968	52	651	220	2,177	33,000
1969	71	831	257	1,797	72,176
1970	98	1,075	338	3,683	83,503
1971	103	1,133	374	3,321	85,479
1972	111	1,265	406	1,491	129,860
1973	119	1,363	429	2,499	125,317
1974	145	1,400	484	67,955	103,763
1975	136	1,292	452	2,588	91,532
1976	127	1,234	423	16,005	90,835
1977	169	1,632	595	5,053	133,804
1978	180	1,119	577	20,070	89,918
1979	186	738	598	4,563	58,359
1980	195	1,135	562	4,730	48,302
1981	153	1,376	479	3,554	36,955
1982	128	972	371	1,954	26,604
1983	138	867	386	3,036	24,502

Fiscal Year	No. License	Trips	No. Reports	No. Caught	Lbs. Caught
1984	194	1,688	607	7,895	57,637
1985	160	1,837	501	4,761	50,425
1986	204	2,022	670	7,001	57,333
1987	247	2,526	785	8,153	71,628
1988	211	2,106	596	8,489	58,079
1989	208	2,134	610	6,494	47,015
1990	165	1,649	510	3,424	29,992
1991	175	1,551	535	3,966	30,730
1992	206	1,796	613	4,775	38,103
1993	195	1,887	564	5,575	41,109
1994	192	1,866	602	5,524	41,601
1995	186	2,033	600	4,536	55,517
1996	212	2,136	632	5,745	41,700
1997	207	1,832	606	5,407	38,267
1998	224	2,253	718	8,324	43,896
1999	214	1,972	714	5,625	35,968
2000	190	2,306	722	8,036	44,732
2001	185	2,384	685	6,534	52,219
2002	183	2,308	682	6,252	48,262
2003	150	2,264	606	21,658	46,540
2004	131	2,092	544	15,049	44,820
2005	103	2,185	448	8,585	46,550
2006	124	1,702	447	10,301	37,217
2007	112	1,485	432	15,036	33,332
2008	126	1,451	460	10,510	37,506
2009	135	1,737	500	18,247	57,779
2010	151	1,945	576	16,664	66,268
2011	149	2,150	617	29,644	67,042
2012	147	1,945	587	50,022	70,837
2013	144	1,951	624	21,237	78,325
2014	132	1,748	564	19,182	72,963
2015	121	1,335	452	22,631	56,162
2016	81	1,101	352	31,643	51,315
2017	75	791	319	65,318	28,980
10-year avg.	**130**	**1,687**	**518**	**23,486**	**59,230**
20-year avg.	**151**	**1,908**	**567**	**16,531**	**51,539**

1.5.4 Top Four Species per Gear Type

1.5.4.1 Hand pick

The top gear for this group category is hand pick (i.e. gleaning). Fishers typically use their hands to gather seaweed or use an instrument such as a knife to harvest opihi from the shoreline. Two specific species codes were established in 2002 for opihi, the yellow foot and black foot species. Prior to 2002, all opihi species were reported under "miscellaneous opihi". The specific limu species codes were established in 1985. Prior to 1985, all seaweed species were reported under "miscellaneous limu". When the revised fishing reports were implemented in October 2002, DAR launched an outreach campaign to inform fishers to report specific opihi and limu species.

Table 37. HDAR MHI fiscal annual mollusk and limu catch (lbs.) summary (1966-2017) by hand picking.

Fiscal Year	Opihi		Opihi'alina		Wawaeiole		Limu kohu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	13	13,989	NULL	NULL	NULL	NULL	NULL	NULL
1967	40	36,000	NULL	NULL	NULL	NULL	NULL	NULL
1968	26	22,994	NULL	NULL	NULL	NULL	NULL	NULL
1969	36	23,818	NULL	NULL	NULL	NULL	NULL	NULL
1970	41	20,446	NULL	NULL	NULL	NULL	NULL	NULL
1971	46	17,229	NULL	NULL	NULL	NULL	NULL	NULL
1972	44	16,689	NULL	NULL	NULL	NULL	NULL	NULL
1973	46	17,169	NULL	NULL	NULL	NULL	NULL	NULL
1974	51	19,558	NULL	NULL	NULL	NULL	NULL	NULL
1975	46	14,277	NULL	NULL	NULL	NULL	NULL	NULL
1976	47	18,090	NULL	NULL	NULL	NULL	NULL	NULL
1977	54	10,494	NULL	NULL	NULL	NULL	NULL	NULL
1978	51	14,267	NULL	NULL	NULL	NULL	NULL	NULL
1979	51	14,146	NULL	NULL	NULL	NULL	NULL	NULL
1980	48	8,435	NULL	NULL	NULL	NULL	NULL	NULL
1981	33	7,231	NULL	NULL	NULL	NULL	NULL	NULL
1982	28	6,050	NULL	NULL	NULL	NULL	NULL	NULL
1983	32	4,765	NULL	NULL	NULL	NULL	NULL	NULL
1984	28	5,708	NULL	NULL	NULL	NULL	NULL	NULL
1985	27	4,850	NULL	NULL	n.d.	n.d.	n.d.	n.d.
1986	61	10,607	NULL	NULL	6	4,238	9	2,119
1987	88	16,748	NULL	NULL	12	5,661	23	5,373
1988	70	11,989	NULL	NULL	6	6,254	14	2,313
1989	67	11,914	NULL	NULL	3	1,260	13	2,600
1990	56	7,848	NULL	NULL	4	1,441	12	3,319
1991	55	7,618	NULL	NULL	4	1,954	24	3,180

Fiscal Year	Opihi		Opihi'alina		Wawaeiole		Limu kohu	
	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught	No. License	Lbs. Caught
1992	55	9,271	NULL	NULL	9	1,982	13	1,354
1993	38	5,587	NULL	NULL	6	2,529	14	1,709
1994	40	9,879	NULL	NULL	5	820	21	3,101
1995	50	13,462	NULL	NULL	7	1,086	19	2,868
1996	52	14,012	NULL	NULL	6	1,879	14	2,592
1997	45	10,291	NULL	NULL	6	2,346	17	3,547
1998	55	11,886	NULL	NULL	n.d.	n.d.	23	2,999
1999	43	12,028	NULL	NULL	n.d.	n.d.	9	1,832
2000	35	10,338	NULL	NULL	5	3,129	16	1,608
2001	31	12,385	NULL	NULL	5	7328	15	1,941
2002	28	12,847	NULL	NULL	6	3550	10	2,351
2003	21	5,145	15	7,300	4	2,694	10	2,606
2004	14	1709	15	8,685	n.d.	n.d.	12	3,179
2005	5	278	10	8,240	n.d.	n.d.	7	1,728
2006	7	403	11	8,364	n.d.	n.d.	7	2,163
2007	11	939	14	6,487	5	2,158	12	1,480
2008	12	372	25	6,993	5	4,834	9	3,061
2009	12	2,782	19	14,866	9	4,013	12	3,120
2010	22	5,348	28	19,521	7	5,317	14	4,243
2011	14	2,984	18	16,183	5	5,458	10	4,643
2012	12	3,418	30	15,129	6	10,643	10	5,454
2013	6	1,958	18	16,475	8	18,864	9	4,895
2014	7	4,902	19	23,479	5	2,058	9	4,659
2015	11	2,574	19	14,390	3	348	12	5,065
2016	5	2,180	15	9,722	n.d.	n.d.	7	3,492
2017	10	1,658	15	7,380	NULL	NULL	11	4,877
10-year avg.	**11**	**2,750**	**21**	**14,373**	**5**	**5,373**	**11**	**4,023**
20-year avg.	**20**	**5,241**	**18**	**12,595**	**5**	**4,092**	**12**	**3,209**

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

1.5.4.2 Spear

For the secondary gear in the MHI mollusk and limu fisheries, spear, the driver species is octopus. There are two specific species of octopus that distinguish the daytime species (*O. cyanea*) from nighttime (*O. ornatus*) and were established in 2002. Prior to 2002, all octopus species were reported as “miscellaneous octopus”. When the revised fishing reports were implemented in October 2002, DAR launched an outreach campaign to ask fishers to report specific octopus species. Because the use of spear may or may not include a SCUBA apparatus by definition, it is possible that the introduction of SCUBA may have increased fishing power and contributed to an overall increase in octopus landings. It should be noted that the miscellaneous opihi and limu species taken by this gear type are probably reporting discrepancies. Starting in 2002, fishers were contacted to verify the potential discrepancy, with the report remaining unchanged if there was no response.

Table 38. HDAR MHI fiscal annual mollusk and limu catch (lbs.) summary (1966-2017) by spear.

Fiscal Year	Octopus (misc.)		He'e (Day tako)	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	15	4,704	NULL	NULL
1967	20	6,573	NULL	NULL
1968	15	5,622	NULL	NULL
1969	18	4,809	NULL	NULL
1970	27	4,609	NULL	NULL
1971	30	5,548	NULL	NULL
1972	38	9,003	NULL	NULL
1973	41	7,358	NULL	NULL
1974	54	9,234	NULL	NULL
1975	59	9,637	NULL	NULL
1976	51	7,237	NULL	NULL
1977	58	12,594	NULL	NULL
1978	81	14,793	NULL	NULL
1979	81	13,712	NULL	NULL
1980	74	16,100	NULL	NULL
1981	54	11,130	NULL	NULL
1982	45	7,131	NULL	NULL
1983	44	6,605	NULL	NULL
1984	66	13,298	NULL	NULL
1985	63	10,544	NULL	NULL
1986	89	14,814	NULL	NULL
1987	73	20,881	NULL	NULL
1988	68	13,547	NULL	NULL
1989	71	15,351	NULL	NULL
1990	52	6,881	NULL	NULL
1991	58	7,293	NULL	NULL
1992	71	9,354	NULL	NULL
1993	71	10,973	NULL	NULL
1994	75	12,252	NULL	NULL
1995	74	11,505	NULL	NULL

Fiscal Year	Octopus (misc.)		He'e (Day tako)	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1996	94	11,663	NULL	NULL
1997	89	14,233	NULL	NULL
1998	100	17,594	NULL	NULL
1999	94	11,668	NULL	NULL
2000	84	18,924	NULL	NULL
2001	80	18,857	NULL	NULL
2002	73	15,002	NULL	NULL
2003	48	11,536	33	5,340
2004	17	1,012	51	12,592
2005	20	2,144	45	13,028
2006	4	630	56	11,489
2007	n.d.	n.d.	47	12,472
2008	NULL	NULL	62	14,420
2009	5	133	68	21,865
2010	8	141	63	22,351
2011	n.d.	n.d.	75	27,910
2012	4	74	66	29,521
2013	13	678	69	28,045
2014	4	468	61	29,875
2015	6	173	55	29,358
2016	5	251	33	30,688
2017	8	207	33	11,672
10-year avg.	**6**	**223**	**60**	**24,667**
20-year avg.	**35**	**5,980**	**56**	**20,652**

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

1.5.4.3 Inshore Handline

Another popular method used to harvest octopus, especially the daytime species (*O. cyanea*), is using a cowrie shell dragged by handline along the seafloor, reported as "inshore handline". It should be noted that miscellaneous hihiwai and limu species taken by this gear type are probably reporting discrepancies. Starting in 2002, fishers were contacted to verify potential discrepancies, with reports remaining unchanged if there was no response.

Table 39. HDAR MHI fiscal annual mollusk and limu catch (lbs.) summary (1966-2017) by inshore handline.

Fiscal Year	Octopus (misc.)		He'e (day tako)	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1966	6	139	NULL	NULL

Fiscal Year	Octopus (misc.)		He‘e (day tako)	
	No. License	Lbs. Caught	No. License	Lbs. Caught
1967	7	117	NULL	NULL
1968	4	83	NULL	NULL
1969	5	43	NULL	NULL
1970	6	423	NULL	NULL
1971	6	69	NULL	NULL
1972	8	249	NULL	NULL
1973	12	482	NULL	NULL
1974	15	400	NULL	NULL
1975	12	254	NULL	NULL
1976	9	459	NULL	NULL
1977	13	340	NULL	NULL
1978	29	1,920	NULL	NULL
1979	43	3,927	NULL	NULL
1980	47	5,377	NULL	NULL
1981	49	5,003	NULL	NULL
1982	35	2,914	NULL	NULL
1983	39	6,090	NULL	NULL
1984	56	14,503	NULL	NULL
1985	46	7,914	NULL	NULL
1986	43	10,429	NULL	NULL
1987	44	12,402	NULL	NULL
1988	46	17,047	NULL	NULL
1989	33	5,390	NULL	NULL
1990	30	3,893	NULL	NULL
1991	25	5,635	NULL	NULL
1992	45	6,322	NULL	NULL
1993	44	8,729	NULL	NULL
1994	41	5,333	NULL	NULL
1995	30	4,566	NULL	NULL
1996	37	7,315	NULL	NULL
1997	40	4,468	NULL	NULL
1998	46	6,874	NULL	NULL
1999	46	5,798	NULL	NULL
2000	41	6,264	NULL	NULL
2001	40	5,966	NULL,	NULL
2002	42	7,653	NULL	NULL
2003	31	6,442	7	735
2004	12	1,021	22	5,994
2005	12	1,099	14	4,832

Fiscal Year	Octopus (misc.)		He'e (day tako)	
	No. License	Lbs. Caught	No. License	Lbs. Caught
2006	n.d.	n.d.	23	7,416
2007	NULL	NULL	15	7,156
2008	NULL	NULL	13	3,960
2009	NULL	NULL	19	7,399
2010	n.d.	n.d.	16	4,622
2011	NULL	NULL	27	5,427
2012	n.d.	n.d.	19	4,500
2013	7	312	25	5,476
2014	6	153	19	5,903
2015	5	232	24	3,341
2016	3	297	14	4,259
2017	NULL	NULL	14	2,505
10-year avg.	**4**	**174**	**19**	**5,204**
20-year avg.	**21**	**2,915**	**18**	**5,073**

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

1.5.5 Catch Parameters by Gear

Table 40. Time series of CPUE by dominant gear from mollusk and limu (1966-2017).

Fiscal Year	Handpicked				Spear				Inshore Handline			
	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE	No. Lic.	No. Trips	Lbs. Caught	CPUE
1966	13	172	14,584	84.79	15	131	4,704	35.91	6	16	139	8.69
1967	41	783	36,210	46.25	20	128	6,573	51.35	7	15	117	7.80
1968	26	454	23,766	52.35	16	120	5,813	48.44	4	6	83	13.83
1969	37	415	23,968	57.75	18	101	4,809	47.61	5	8	43	5.38
1970	43	401	21,089	52.59	27	126	4,609	36.58	6	21	423	20.14
1971	48	372	17,980	48.33	30	196	5,548	28.31	6	9	69	7.67
1972	45	273	18,519	67.84	38	209	9,003	43.08	8	15	249	16.60
1973	47	275	19,462	70.77	41	235	7,358	31.31	12	37	482	13.03
1974	54	389	24,946	64.13	54	302	9,234	30.58	15	28	400	14.29
1975	49	363	17,553	48.36	60	322	9,709	30.15	12	18	254	14.11
1976	47	304	18,283	60.14	51	287	7,237	25.22	9	25	459	18.36
1977	54	247	10,518	42.58	58	450	12,854	28.56	13	20	340	17.00
1978	52	222	14,375	64.75	82	430	14,803	34.43	29	77	1,920	24.94
1979	51	183	14,174	77.45	81	335	13,712	40.93	43	83	3,927	47.31
1980	48	199	8,435	42.39	77	415	16,860	40.63	47	139	5,377	38.68
1981	33	199	7,231	36.34	54	394	11,130	28.25	49	187	5,003	26.75
1982	28	156	6,054	38.81	45	284	7,154	25.19	35	156	2,914	18.68
1983	33	154	4,871	31.63	47	298	6,891	23.12	39	210	6,090	29.00

Fiscal Year	Handpicked				Spear				Inshore Handline			
	No. Lic.	**No. Trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. Trips**	**Lbs. Caught**	**CPUE**	**No. Lic.**	**No. Trips**	**Lbs. Caught**	**CPUE**
1984	29	135	5,760	42.67	66	478	13,543	28.33	60	409	15,484	37.86
1985	27	170	5,600	32.94	63	494	10,607	21.47	46	296	7,914	26.74
1986	82	891	25,441	28.55	89	582	14,879	25.57	43	392	10,429	26.60
1987	126	1,373	32,771	23.87	74	694	21,164	30.50	44	387	12,402	32.05
1988	95	1,113	25,112	22.56	68	482	13,547	28.11	46	463	17,047	36.82
1989	100	1,414	24,568	17.37	72	530	15,565	29.37	33	175	5,390	30.80
1990	95	1,212	18,718	15.44	52	279	6,881	24.66	30	143	3,893	27.22
1991	102	1,108	17,336	15.65	58	307	7,293	23.76	25	123	5,635	45.81
1992	101	1,068	17,354	16.25	71	496	9,354	18.86	45	201	6,322	31.45
1993	86	1,056	14,088	13.34	71	451	10,973	24.33	44	323	8,729	27.02
1994	90	1,115	17,676	15.85	75	537	12,252	22.82	41	185	5,333	28.83
1995	91	1,293	20,693	16.00	74	526	11,505	21.87	30	170	4,566	26.86
1996	87	991	21,487	21.68	94	850	11,663	13.72	37	251	7,315	29.14
1997	85	921	18,884	20.50	89	660	14,268	21.62	40	215	4,468	20.78
1998	90	1,046	17,975	17.18	100	920	17,594	19.12	46	242	6,874	28.40
1999	82	952	17,610	18.50	94	738	11,668	15.81	46	245	5,798	23.67
2000	80	1,054	18,559	17.61	84	986	18,924	19.19	41	229	6,264	27.35
2001	74	1,276	27,040	21.19	80	863	18,857	21.85	40	211	5,966	28.27
2002	68	1,354	24,731	18.27	73	698	15,002	21.49	43	210	7,665	36.50
2003	55	1,298	22,055	16.99	60	686	16,876	24.60	33	248	7,176	28.94
2004	45	1,299	23,713	18.25	54	496	13,633	27.49	23	264	7,015	26.57
2005	33	1,294	21,018	16.24	49	572	15,171	26.52	20	275	5,931	21.57
2006	39	742	16,279	21.94	57	604	12,119	20.06	23	300	7,434	24.78
2007	43	540	12,479	23.11	49	627	12,505	19.94	15	250	7,156	28.62
2008	50	640	17,369	27.14	62	561	14,453	25.76	13	169	3,960	23.43
2009	49	723	27,177	37.59	70	725	21,998	30.34	19	233	7,399	31.76
2010	64	923	36,790	39.86	65	698	22,641	32.44	17	216	4,655	21.55
2011	45	973	32,765	33.67	75	880	27,918	31.73	27	208	5,427	26.09
2012	57	795	36,136	45.45	69	907	29,616	32.65	20	193	4,533	23.49
2013	43	824	43,556	52.86	77	871	28,723	32.98	30	219	5,788	26.43
2014	39	683	35,643	52.19	63	800	30,343	37.93	25	183	6,056	33.09
2015	34	487	22,463	46.13	59	680	29,531	43.43	27	103	3,572	34.68
2016	21	336	15,431	45.93	36	620	30,939	49.90	16	87	4,556	52.37
2017	22	301	13,938	46.31	37	382	11,879	31.10	14	51	2,505	49.12
10-year avg.	**45**	**694**	**28,047**	**40.41**	**63**	**738**	**24,889**	**33.72**	**21**	**186**	**5,310**	**28.55**
20-year avg.	**55**	**909**	**24,417**	**26.86**	**68**	**730**	**20,150**	**27.60**	**28**	**215**	**5,885**	**27.37**

1.6 PRECIOUS CORALS FISHERY

1.6.1 Fishery Descriptions

This species group is comprised of any coral of the genus *Corallium* in addition to pink coral (also known as 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)*.

Only selective gear may be used to harvest corals in federal waters. The top gear for this species group is submersible.

1.6.2 Dashboard Statistics

Future reports will include data as resources allow.

1.6.3 Other Statistics

Commercial fishery statistics for the last ten years are unavailable due to confidentiality, as the number of federal permit holders since 2007 has been fewer than three. Future reports will include data as resources and reporting confidentiality thresholds allow.

1.7 HAWAII MARINE RECREATIONAL FISHING SURVEY

1.7.1 Fishery Descriptions

The State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources (DAR) manages the fishery resources within state waters of the Main Hawaiian Islands (MHI). Fishery resources in federal waters are collaboratively managed by DAR, the National Marine Fisheries Service's (NMFS) Pacific Islands Regional Office (PIRO) and Pacific Islands Fisheries Science Center (PIFSC), and the Western Pacific Regional Fishery Management Council (WPRFMC).

DAR manages the collection of both commercial and non-commercial fishery dependent information in both state and federal waters. Regulatory actions in federal waters are typically proposed by NMFS based largely on stock assessments produced by PIFSC staff. Proposed regulations in federal waters are then generally agreed upon by NMFS, DAR, and WPRFMC. These three agencies coordinate management in federal waters to simplify the regulations for the fishing public, prevent overfishing, and manage the fisheries for long-term sustainability. This shared management responsibility is necessary due to the overlap of various fisheries in both state and federal waters. The information in this report is largely based on the data collected by DAR.

1.7.2 Non-Commercial Data Collection Systems

Two independent and complementary surveys were re-initiated in Hawaii in collaboration with NOAA Fisheries' Marine Recreational Fishery Statistics Surveys (MRFSS) starting in 2001. The Hawaii Marine Recreational Fishing Survey (HMRFS) follows the traditional MRFSS on-site Access Point Angler Intercept Survey (APAIS) used to collect non-commercial finfish catch information for shore and private boat fishing modes (Figure 1). The charter boat mode is covered by the State of Hawaii's Commercial Marine License (CML) system whereby all crew members working on charter boats are lawfully required to annually purchase a CML and report catch and trip statistics on a monthly basis to DAR. A local contractor currently conducts the Coastal Household Telephone Survey (CHTS), which utilizes a random-digit-dial sampling method of landline telephones to collect non-commercial effort information for both shore and private boat fishing modes. In 2017, HMRFS consisted of 13 total field surveyors (one on Kauai, one on Maui, one on Molokai, six on Oahu, and four on the Big Island), one data manager, and one project manager. A more detailed description of the current sampling and estimation procedures can be found in Ma and Ogawa (2016).

1.7.2.1 Shore-Based Fishing Effort Prediction Model

Hawaii's coastal terrain varies from sandy beaches to rocky boulders, and people fish accordingly using different type of gears. For effective fishery management, it is helpful to know these spatial varitatations in fishing effort along the shoreline. HMRFS has been colleting non-commercial fishing effort from 98 sites in Hawaii covering differing habitat types (Figure 1). The survey collects both shore- and boat-based fishing effort, but for this model, we only used the shore-based fishing effort data. We combined the shoreline fishing data with 36 spatially explicit environmental variables that potentially affect fishing effort (Table 41) and created a prediction model using boosted regression tree analysis (BRT; Friedman *et al*., 2000).

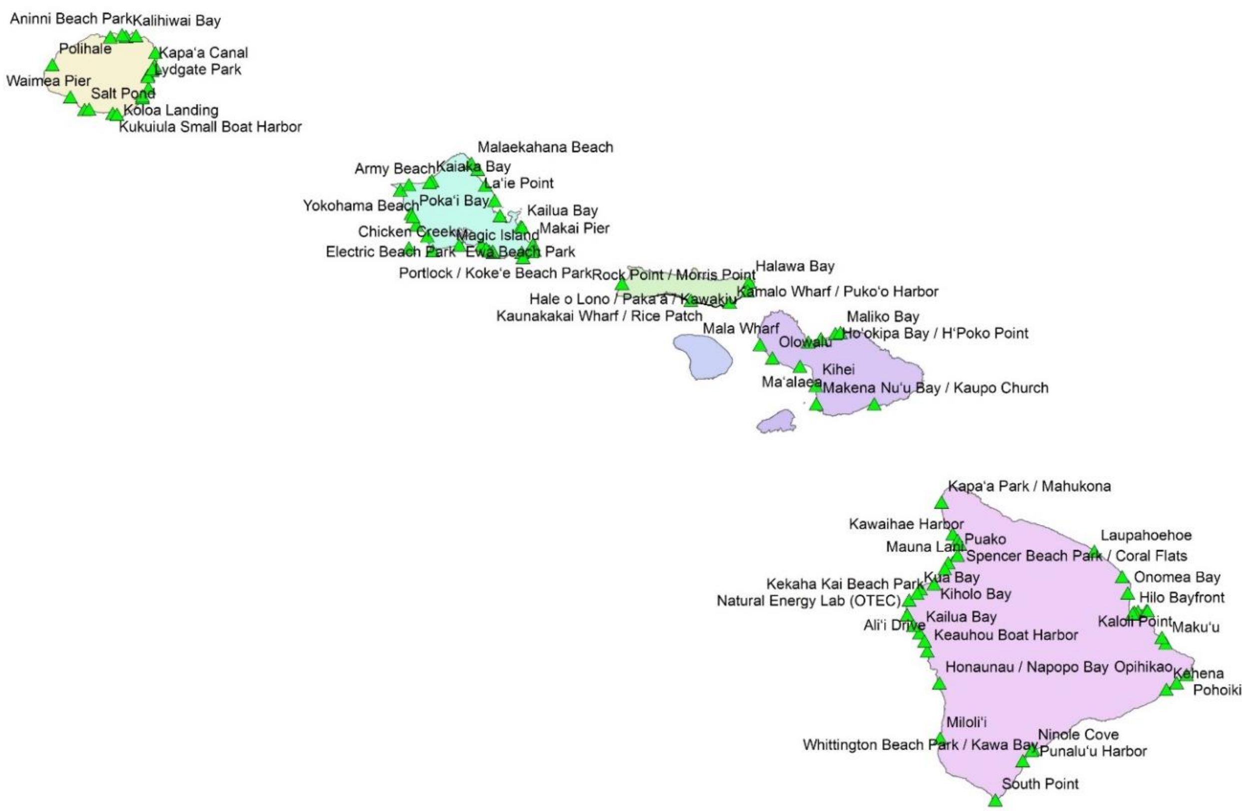

Figure 1. Access point angler intercept survey sites for the Main Hawaiian Islands.

Table 41. List of environmental variables used to create the fishing effort prediction model.

Variable Category	Variable	No. of sites w/ variable	Description	Layer Type	Data Source
Anthropogenic Impact	Accessibility	71	12 classifications scoring the ease of access	Point	Joey Lecky (OTP)

			(combination of access road type and distance to shore)		
	Distance to Humans	71	Sum of human population (from 2010 census blocks) in 15km radius (# of people)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
Oceanographic Variables	Island	71	Each island as independent factors	polygon	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	Wave Power	71	Mean wave power (wave height x wave period) derived from a 10-year hindcast model (kilowatts per meter)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
	Slope of Slope	71	Maximum rate of change in seafloor slope between each grid cell and its neighbors (degrees)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
	Depth	71	Seafloor depth from 5m grid resolution bathymetry synthesis (meters)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
	Max Slope 240	71	Maximum rate of change in seafloor depth between each grid cell and its 240m neighborhood (degrees)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
Productivity	Predicted Biomass_g	71	Total biomass predicted from boosted regression tree models (g/m^2)	60m * 60m raster	Marine Biogeographic Assessment of the Main Hawaiian Islands, Chapter 4 (NCCOS)
Habitat	Unknown	19	Seafloor geomorphology delineated as unknown	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Spur and Groove	0	Seafloor geomorphology	Polygon	Benthic Habitat Map for Main Hawaiian Islands

			delineated as spur and groove		(NCCOS)
	Scatter Coral Rock	5	Seafloor geomorphology delineated as scattered coral/rock	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Sand	41	Seafloor geomorphology delineated as sand	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Rubble	3	Seafloor geomorphology delineated as rubble	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Rock and boulder	34	Seafloor geomorphology delineated as rock/boulder	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Pavement with Sand Channels	2	Seafloor geomorphology delineated as sand channels	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Pavement	33	Seafloor geomorphology delineated as pavement	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Mud	11	Seafloor geomorphology delineated as mud	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Individual Patch Reef	0	Seafloor geomorphology delineated as individual patch reef	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Artificial Habitat	15	Seafloor geomorphology delineated as artificial	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Aggregated Patch Reef	0	Seafloor geomorphology delineated as aggregated patch reef	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
	Aggregate Reef	9	Seafloor geomorphology delineated as aggregate reef	Polygon	Benthic Habitat Map for Main Hawaiian Islands (NCCOS)
Shoreline	8C Sheltered RipRap	9	Sheltered coastline with rip rap	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	8B Sheltered	14	Sheltered	Polyline	Hawaii ESI: Hydro

	Man Made		coastline with man-made structure		(NOAA National Ocean Service, Office of Response and Restoration)
	8A Sheltered Rocky	4	Sheltered coastline with rocky habitat	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	6B RipRap	13	Coastline with rip rap.	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	6A Gravel Beaches	20	Coastline with gravel beach	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	5 Mixed Sand Gravel	13	Coastline with sand and gravel beaches	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	4 Coarse Grained Sand	33	Coastline with grainy sand beaches	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	3A Fine to Medium Sand	10	Coastline with fine to medium grain sand beaches	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	2B Scarps Steep Sloped Muddy	0	Coastline with exposed scarps and steep slopes in clay	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	2A Exposed Wave	15	Coastline with exposed wave-cut platforms in bedrock	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	1B Exposed Solid Man-made	16	Coastline with exposed solid man-made structures	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	1A Exposed Rocky Shores	22	Coastline with exposed rocky cliffs	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	10C Swamps	0	Coastline with	Polyline	Hawaii ESI: Hydro

			freshwater swamps		(NOAA National Ocean Service, Office of Response and Restoration)
	10D Scrub Shrub Wetland	5	Coastline with mangroves	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	10A Saltwater Marsh	7	Coastline with salt and brackish water marsh	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)
	10B Freshwater Marsh	0	Coastline with freshwater marsh	Polyline	Hawaii ESI: Hydro (NOAA National Ocean Service, Office of Response and Restoration)

1.7.2.1.1 Methods

First, the coastline was divided into small, equilateral hexagons of 300 m (Figure 2). These hexagons delineate the spatial extent of each shoreline survey effort.

Figure 2. Example of 300 m hexagons overlaid over the island of Oahu. Green stars indicate a survey site within the area.

Each of the 36 environmental raster layers was overlayed with this hexagon layer and the raster value that fell within each hexagon was averaged using the raster calculator in ArcGIS 10.0. Annual fishing effort was calculated for each hexagon that contained a shoreline survey site for each gear type. In the end, there were 71 hexagons that contained both the survey site (hence the fishing effort information) and environment variable information. These 71 hexagons were used to fit the BRT model to examine the associations between environmental variables and annual fishing effort for the three common gear types (rod and reel, spear, and throw net). We further used BRT to predict and map the distributions of fishing effort occurring in individual hexagons for all the coastlines along the Main Hawaiian Islands using the environmental variables. BRT stems from machine learning and improves standard regression tree modelling by adding a stochastic component (Friedman *et al*., 2000). All BRT analyses were carried out in R using the GBM package developed by Ridgeway (2010) and supplemented with functions from Elith *et al.* (2008).

1.7.2.1.2 Results

Important environmental predictors for all three gear types were rugosity (measured in max slope) and mean distance to humans (Table 42). Other factors that were commonly important were wave power, rocky boulder/pavement habitat, depth, and fish abundance (measured in biomass) in the water. Islands of Kahoolawe, Lanai, Molokai, and Niihau had to be removed from our prediction model due to the low number or absence of survey sites. The total fishing effort predicted was 8,007,030 gear hours from the model for rod and reel (Figure 3), 319,140 gear hours for spear fishing (Figure 4), and 188,010 gear-hours for throw net (Figure 5) for the combined remaining islands of Kauai, Oahu, Maui, and Hawaii.

Table 42. Top 10 environmental variables showing the relative influence (in percentage) on fishing effort (in gear-hours) from the boosted regression tree (BRT) models for each selected gear type across the Main Hawaiian Islands. The spatial predictions derived from models are shown in Figures 3 through 5.

Variable Categories	Environmental Variable	Rod	ThrowNet	Spear
Oceanographic	Island	21.86	24.09	6.41
Oceanographic	Max Slope	11.17	15.19	20.00
Anthropogenic	Mean Distance to Human	8.80	7.93	17.55
Habitat	Rock and Boulder	1.45	16.35	11.88
Oceanographic	Mean Wave Power	8.14	9.64	11.59
Productivity	Biomass (g/m^2)	18.43	3.70	4.63
Oceanographic	Mean Depth (m)	7.27	2.45	6.26
Habtiat	Pavement	12.46	0.64	2.01
Oceanographic	MeanSlopeOfSlope	2.52	4.53	7.90
Habitat	Sand	2.74	4.58	3.16
Coastline	Coarse Grained Sand Beach	0.54	2.04	4.94
Habitat	Mean Percent Coral	0.27	3.71	1.13
Coastline	6A Gravel Beaches	2.92	1.93	0.19
Anthropogenic	Accessibility	0.47	1.75	0.63

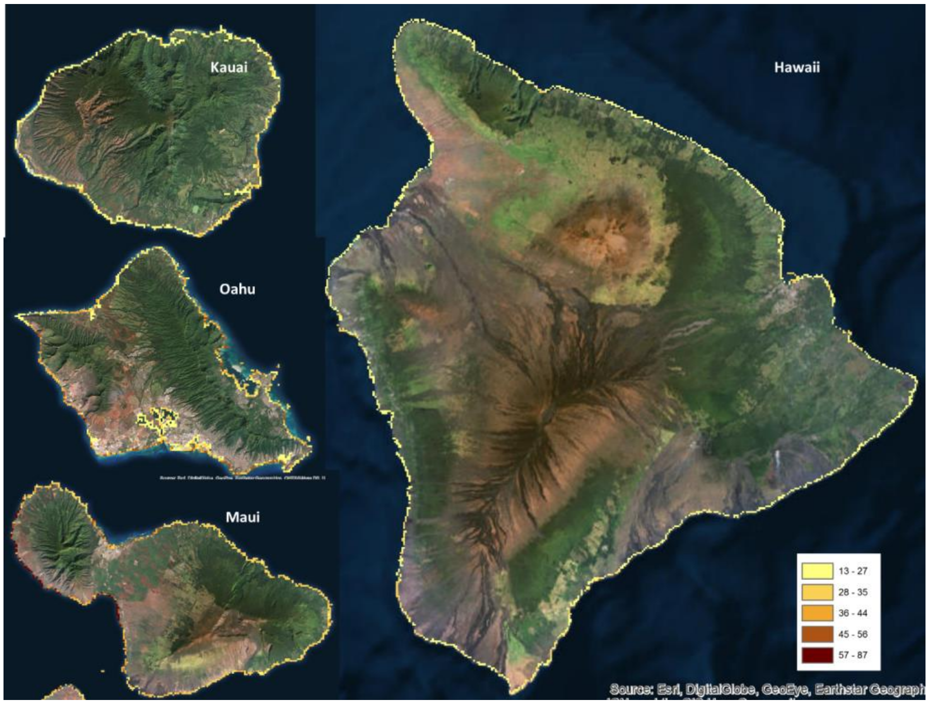

Figure 3. Fishing effort in gear-hours predicted for *rod-and-reel* fishing by a boosted regression tree model for the islands of Kauai, Oahu, Maui, and Hawaii.

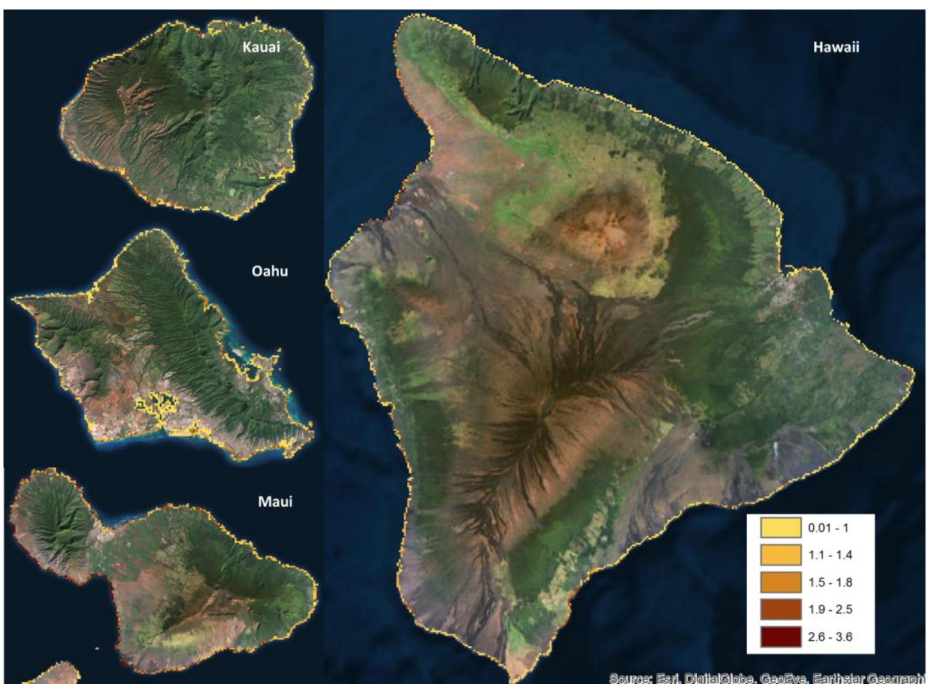

Figure 4. Fishing effort in gear-hours predicted for *spear fishing* by a boosted regression tree model for the islands of Kauai, Oahu, Maui, and Hawaii.

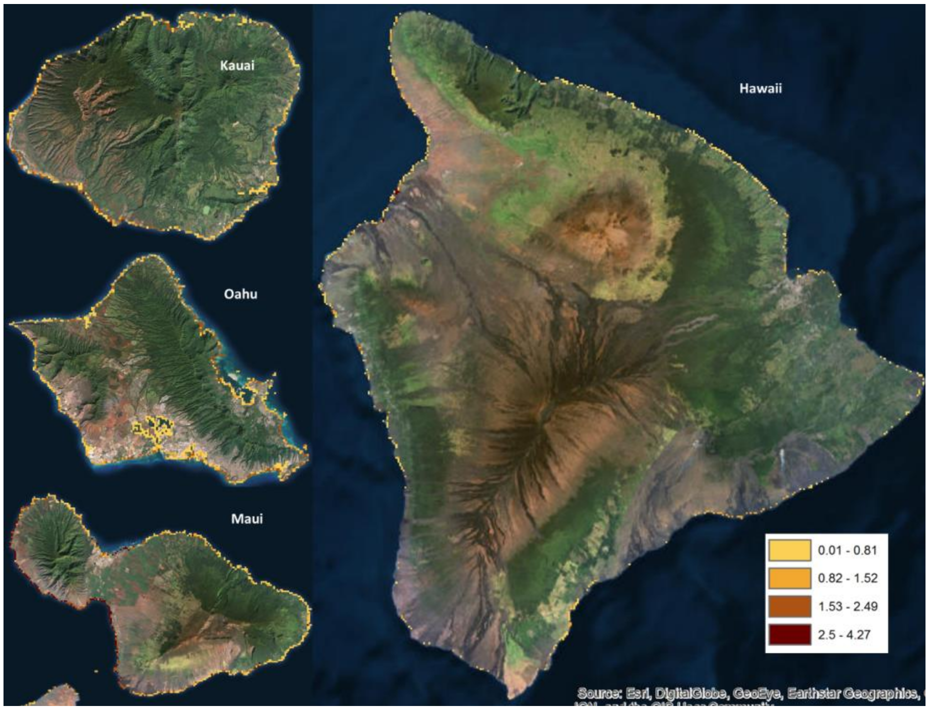

Figure 5. Fishing effort in gear-hours predicted for *throw net fishing* by a boosted regression tree model for the islands of Kauai, Oahu, Maui, and Hawaii.

1.7.2.1.3 Discussion

The ability to spatially predict fishing effort is critical for spatial management plans. The BRT analyses show promise as a predictor of effort because the estimate was similar to that of the fishing effort estimate from the phone survey currently conducted by MRIP. Observational data from HMRFS allow the estimates to be spatially explicit and further allow estimation of CPUE and species catch composition for each gear type. This gives more detailed information on fishing effort than the total statewide values that MRIP currently provides. The detailed information allows the State to explore wider management options that could be more efficient and easier to enforce. For example, being able to see fishing effort by gear type allows the State to look into gear restrictions, and spatially explicit information allows the State to look into fishery management area options.

We plan to further use BRT to estimate CPUE and catch along the coastline to see if gear restrictions imposed on particular areas would be as efficient at conserving species of concern as current statewide regulations. One of the current challenges in using BRT further is the low number of survey sites on remote access areas especially on Lanai, Niihau, and Molokai. The predictions for these areas are not as reliable as predictions made on other areas of the coastline. Future creel survey projects could target these hard-to-access sites and further improve the precision of the predictions.

1.8 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.

1.8.1 Special Coral Reef Ecosystem Permit

Regulations require the special coral reef ecosystem fishing permit for anyone fishing for coral reef ecosystem management unit species (MUS) in a low-use 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 ecosystem MUS while fishing for bottomfish MUS, crustacean MUS, 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 ecosystem MUS caught in a low-use MPA.

1.8.2 Main Hawaiian Islands Non-Commercial Bottomfish

Regulations require this permit for any person, including vessel owners, fishing for bottomfish MUS in the EEZ around the main Hawaiian Islands. If the participant possesses a current State of Hawaii Commercial Marine License, or is a charter fishing customer, he or she is not required to have this permit.

1.8.3 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 (Federal Register notice of final rule, 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).

1.8.4 Western Pacific Crustaceans Permit

Regulations require a permit for the owner of a U.S. fishing vessel used to fish for lobster or deepwater shrimp in the EEZ around American Samoa, Guam, Hawaii, and the Pacific Remote Islands Areas, and in the EEZ seaward of three nautical miles of the shoreline of the Commonwealth of the Northern Mariana Islands.

Table 43 provides the number of permits issued to Hawaii FEP fisheries between 2007 and 2017. Historical data are from the PIFSC, and 2017 data are from the PIRO Sustainable Fisheries Division permits program as of January 5, 2018.

Table 43. Number of federal permits in Hawaii FEP fishery from 2007-2017.

Year	Special Coral Reef Ecosystem	MHI Non-Commercial Bottomfish	Precious Coral	Crustacean Shrimp	Crustacean Lobster
2007			2		2
2008		76	1		2
2009		91	2		3
2010		28	2		3
2011	1	19	2		
2012	1	11	2	2	1
2013		3	1	5	2
2014		3	1	7	2
2015		2	1	5	2
2016	1	1	1	4	1
2017	1	1	1	6	1

1.9 STATUS DETERMINATION CRITERIA

1.9.1 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 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 and the coral reef species complex. 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 are not specified in this document. The latest estimate published annually in the 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 44.

Table 44. Overfishing threshold specifications for Hawaiian bottomfish and NWHI lobsters Note that the MFMT listed here only applies to Hawaiian bottomfish.

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_{AVE}, where E_{AVE} 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 particular 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 (SSB_{Pt}) 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 $SSBP_{RMIN}$. 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 SSBP ratio, are specified as indicated in Table 45. Again, E_{MSY} is used as a proxy for F_{MSY}.

Table 45. 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.

1.9.2 Coral Reef Fishery

Available biological and fishery data are poor for all coral reef ecosystem management unit species (MUS) in the Hawaiian Islands. There is scant information on the life histories, ecosystem dynamics, fishery impact, community structure changes, yield potential, and management reference points for many coral reef ecosystem species. Additionally, total fishing effort cannot be adequately partitioned between the various MUS for any fishery or area. Biomass, maximum sustainable yield, and fishing mortality estimates are not available for any single MUS. Once these data are available, fishery managers can establish limits and reference points based on the multi-species coral reef ecosystem as a whole.

The MSY control rule should be applied to the individual species in a multi-species stock when possible. When this is not possible, MSY may be specified for one or more species; these values can be used as indicators for the multi-species stock's MSY.

Individual species that are part of a multi-species complex will respond differently to an OY-determined level of fishing effort (F_{OY}). Thus, for a species complex that is fished at F_{OY}, managers still must track individual species' mortality rates in order to prevent species-specific population declines that would lead to depletion.

For the coral reef fishery, the multi-species complex as a whole is used to establish limits and reference points for each area. Available data for a particular species are used to evaluate the status of individual MUS stocks in order to prevent recruitment overfishing when possible. When better data and the appropriate multi-species stock assessment methodologies become available, all stocks will be evaluated independently without proxy.

1.9.2.1 Establishing Reference Point Values

Standardized values of catch per unit effort (CPUE) and effort (E) are used to establish limit and reference point values, which act as proxies for relative biomass and fishing mortality, respectively. Limits and reference points are calculated in terms of $CPUE_{MSY}$ and E_{MSY} included in Table 46.

Table 46. Status determination criteria for the CREMUS using CPUE-based proxies.

Value	Proxy	Explanation
MaxFMT (F_{MSY})	E_{MSY}	0.91 $CPUE_{MSY}$
F_{OY}	0.75 E_{MSY}	suggested default scaling for target
B_{MSY}	$CPUE_{MSY}$	operational counterpart
B_{OY}	1.3 $CPUE_{MSY}$	simulation results from Mace (1994)
MinSST	0.7 $CPUE_{MSY}$	suggested default (1-M)B_{MSY} with M=0.3*
B_{FLAG}	0.91 $CPUE_{MSY}$	suggested default (1-M)B_{OY} with M=0.3*

When reliable estimates of E_{MSY} and $CPUE_{MSY}$ are not available, they are generated from time series of catch and effort values, standardized for all identifiable biases using the best available analytical tools. $CPUE_{MSY}$ is calculated as one-half a multi-year moving average reference CPUE ($CPUE_{REF}$).

1.9.3 Current Stock Status

1.9.3.1 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 Main Hawaiian Island 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 a typical bottom fishing trip is comprised primarily of these seven species.

Generally, data are only available on commercial landings by species and CPUE for the multi-species complexes as a whole. The assessment utilized a state-space surplus production model with explicit process and observation error terms (Meyer and Millar, 1999). Determinations of overfishing and overfished status can then be made by comparing current biomass and harvest rates to MSY-level reference points. As of 2015, the MHI Deep 7 bottomfish complex is not subject to overfishing and is not overfished (Table 47).

Table 47. Stock assessment parameters for the Main Hawaiian Island Deep 7 bottomfish complex (from Boggs memo, 2015).

Parameter	Value	Notes	Status
MSY	0.404 ± 0.156	Expressed in million lbs. (± std. error)	
H_{2013}	3.8 ± 1.4	Expressed in percentage	
H_{MSY}	6 ± 2.1	Expressed in percentage (± std. error)	
H/H_{MSY}	0.627		No overfishing occurring
B_{2013}	13.34 ± 5.397	Expressed in million lbs.	
B_{MSY}	14.51 ± 4.267	Expressed in million lbs. (± std. error)	
B/ B_{MSY}	0.930		Not overfished

1.9.3.2 Coral reef

The application of the SDCs for the management unit species in the coral reef fisheries is limited due to various challenges. First, the thousands of species included in the coral reef MUS makes the SDC and status determination impractical. Second, the CPUE derived from the creel survey is based on the fishing method and there is no species-specific CPUE information available. In order to allocate the fishing method level CPUE to individual species, the catch data (the value of catch is derived from CPUE hence there is collinearity) will have to be identified to species level and CPUE will be parsed out by species composition. The third challenge is that there is very little species-level identification applied to the creel surveys. There has been no attempt to estimate MSY for the coral reef MUS until the 2007 re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) that requires the Council to specify ACLs for species in the FEPs.

For ACL specification purposes, MSYs in the coral reef fisheries are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber, 2014). This method estimates MSY using plausible combination rates of population increase (denoted by *r*) and carrying capacity (denoted by *k*) assumed from the catch time series, resilience characteristics (from FishBase), and biomass from existing underwater census surveys done by the Pacific Island Fisheries Science Center. This method was applied to species complexes grouped by taxonomic families. The most recent MSY estimates are found in Table 48. The SSC utilized the MSYs for the coral reef MUS complexes as the OFLs.

Table 48. Best available MSY estimates for the CREMUS in Hawaii.

Fishery	Management Unit Species	MSY (lbs.)
Coral Reef Ecosystem	*Selar crumenopthalmus* - akule	1,150,800
	Decapterus macarellus - opelu	538,000
	Acanthuridae - surgeonfish	445,500
	Carangidae - jacks	185,100

	Carcharhinidae - reef sharks	12,400
	Crustaceans - crabs	43,100
	Holocentridae - squirrelfish	159,800
	Kyphosidae - rudderfish	122,800
	Labridae - wrasse	229,200
	Lethrinidae - emperors	39,600
	Lutjanidae - snappers	359,300
	Mollusk - turbo snails, octopus, etc.	50,300
	Mugilidae - mullets	24,600
	Mullidae - goatfish	195,700
	Scaridae - parrotfish	271,500
	Serranidae - groupers	141,300
	All other CREMUS combined	540,800

1.9.3.3 Crustacean

The application of the SDCs for the crustacean MUS is limited to the NWHI lobster stock. Previous studies conducted in the Main Hawaiian Islands 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 (Tagami and Ralston, 1988).

A stock assessment model was developed in 2014 in an attempt to understand and determine the status of the Kona crab stock in the MHI (Thomas *et al*., 2015). This assessment utilized a non-equilibrium generalized production model (using the Stock-Production Model Incorporating Covariate –ASPIC statistical routine) to estimate parameters needed to determine stock status. Based on this, the Kona crab stock is overfished and potentially rebuilding, but not experiencing overfishing (Table 49)

Table 49. Stock assessment parameters for the Hawaiian Kona crab stock.

Parameter	Value	Notes	Status
MSY	40,400	Expressed in lbs.	
H_{2007}		Expressed in percentage	
H_{MSY}	0.2534	Expressed in percentage (± std error)	
H/H_{MSY}	0.9218		No overfishing occurring
B_{2007}		Expressed in million pounds	
B_{MSY}	159,500	Expressed in lbs.	
B/ B_{MSY}	0.1810		Overfished

For ACL-specification purposes, MSY for spiny lobsters are determined by using the Biomass-Augmented Catch-MSY approach (Sabater and Kleiber, 2014). This method estimates MSY using plausible combination rates of population increase (denoted by *r*) and carrying capacity (denoted by *k*) assumed from the catch time series, resilience characteristics (from FishBase), and biomass from existing underwater census surveys done by the Pacific Island Fisheries

Science Center. This method was applied to species complexes grouped by taxonomic families. The most recent MSY estimates are found in Table 50.

Table 50. Best available MSY estimates for the crustacean MUS in Hawaii.

Fishery	Management Unit Species	MSY (lbs.)
Crustacean	Deep-water shrimp	598,328
	Spiny lobsters	20,400
	Slipper lobsters	N/A
	Kona crab	40,400

SOURCE: Deepwater shrimp MSY – Tagami and Ralston, 1988; Spiny lobster MSY – WPRFMC, 2014; Kona crab – Thomas, 2011.

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

1.10.1 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 and NMFS, 2011). The process starts with the use of the best scientific information available (BSIA) in the form of, but not limited to, stock assessments, published paper, reports, or available data. This information is classified into the different Tiers in the control rule ranging from Tier 1 (most information available, typically an assessment) to Tier 5 (catch-only information). The control rules are applied to the BSIA. Tiers 1 to 3 would involve conducting a Risk of Overfishing Analysis (denoted by P*) to quantify the scientific uncertainties around the assessment to specify the Acceptable Biological Catch (ABC). This would lower the ABC from the over-fishing limit (OFL) (MSY-based). A Social, Ecological, Economic, and Management (SEEM) Uncertainty Analysis is performed to quantify the uncertainties from the SEEM factors. The buffer is used to lower the ACL from the ABC. For Tier 4, which consists of stocks with MSY estimates but no active fisheries, the control rule is 91% of MSY. For Tier 5 which has catch-only information, the control rule is a third reduction in the median catch depending on the qualitative evaluation on what the stock status is based on expert opinion. ACL specification can choose from a variety of method including the above mentioned SEEM analysis or a percentage buffer (percent reduction from ABC based on expert opinion) or the use of an Annual Catch Target. Specifications are done on an annual basis but the Council normally specifies a multi-year specification.

The Accountability Measure for the coral reef and bottomfish fisheries in Hawaii is an overage adjustment. The ACL is downward adjusted with the amount of overage from the ACL based on a three-year running average.

1.10.2 Current OFL, ABC, ACL, and Recent Catch

The most recent multiyear specification of OFL, ABC, and ACL for the some coral reef species complex, non-Deep 7, crustaceans, and precious coral fisheries was completed in the 160th Council meeting from June 25 to 27, 2014. The specification covers fishing years 2015, 2016, 2017, and 2018 for the coral reef MUS complexes. The fisheries for deep sea corals remain inactive. ACLs were not specified for Kona crab, non-Deep 7 bottomfish, or coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these MUS (50 CFR Part 665). A P* and SEEM analysis was performed for this multiyear specification (NMFS 2015a).

At the 171st Council meeting in Pago Pago American Samoa from October 17 to 19, 2017, the Council specified new ACLs for five coral reef fish species and four species complexes. There was one assessed species (*Monotaxis grandoculis*) that currently represents the family Lethrinidae where the ACL had been retained. This new specification was based on the benchmark assessment of 27 coral reef fish species in the main Hawaiian Islands. This is a multi-year specification covering fishing year 2018, 2019, and 2020. A P* analysis was performed for this multiyear specification. There were only five species of the 27 species assessed that the SSC deemed adequate for a single species harvest limit specification. The rest of the species were grouped on a family level and the assessed species were treated as indicator species for the family. The indicator species for Family Acanthuridae are *Acanthurus dussumieri* (palani), *Naso lituratus* (umaumalei), *N. brevirostris* (kala lolo), *N. unicornis* (kala), *A. blochii* (pualu), and *N. hexacanthus* (kala lolo). The indicator species for Family Carangidae are *Caranx melampygus* (omilu), *C. ignobilis* (ulua aukea), and *Carangoides orthogrammus* (ulua). The indicator species for Family Mullidae are *Parupeneus insularis* (munu), *P. cyclostomus* (moano), *Mulloidichthys vanicolensis* (weke'ula), *M. flavolineatus* (weke'a), and *M. pfluegeri* (weke nono). Finally, the indicator species for Family Scaridae are *Scarus dubius* (lauia), *S. psittacus* (uhu), *S. rubroviolaceus* (uhu ele'ele), *Chlorurus spilurus* (uhu), *Chlorurus perspicillatus* (uhu uliuli), and *Calotomus carolinus* (ponuhunuhu).

ACLs were not specified for Kona crab, non-Deep 7 bottomfish, or coral reef ecosystem MUS because NMFS has recently acquired new information that require additional environmental analyses to support the Council's ACL recommendations for these MUS (50 CFR Part 665). The ACL described in Table 50 are the Council recommended ACLs from the 171st meeting.

The most recent multiyear specification of OFL, ABC, and ACL for the main Hawaiian island Deep 7 bottomfish complex was completed at the 163rd meeting in June of 2015. The specification covers fishing year 2015-2016, 2016-2017, and 2017-2018. This multi-year specification utilized a phased-in approach (Slow-up, Fast-down) to alleviate the impact of a sudden drop of the new catch limit. Note that the MHI Deep 7 stock complex operates based on Fishing Year, and is currently still open. Recent average catch for the MHI Deep 7 Bottomfish stock complex (266,550 lbs.) accounted for 87.1% of its prescribed ACL (306,000 lbs.; Table 51). A P* and SEEM analysis was also performed for this multiyear specification (NMFS 2015b).

Table 51. Hawaii ACL table with 2017 catch (lbs.).

Fishery	Management Unit Species	OFL	ABC	ACL	Catch
Bottomfish	MHI Deep 7 stock complex	352,000	326,000	326,000	266,550
	Aprion virescens – uku	N.A.	N.A.	N.A.	10,340
Crustaceans	Deepwater shrimp	N.A.	250,773	250,773	16,139
	Spiny lobster	20,400	15,800	15,000	4,945
	Slipper lobster	N.A.	280	280	N.A.
	Kona crab	N.A.	N.A.	N.A.	1,993
Precious coral	Auau channel black coral	8,250	7,500	5,512	N.A.F.
	Makapuu bed-pink coral	3,307	3,009	2,205	N.A.F.
	Makapuu bed-bamboo coral	628	571	551	N.A.F.
	180 fathom bank-pink coral	734	668	489	N.A.F.
	180 fathom bank-bamboo coral	139	126	123	N.A.F.
	Brooks bank-pink coral	1,470	1,338	979	N.A.F.
	Brooks bank-bamboo coral	280	256	245	N.A.F.
	Kaena point bed-pink coral	220	201	148	N.A.F.
	Kaena point bed-bamboo coral	42	37	37	N.A.F.
	Keahole bed-pink coral	220	201	148	N.A.F.

	Keahole bed-bamboo coral	42	37	37	N.A.F.
	Precious coral in HI exploratory area	N.A.	2,205	2,205	N.A.F.
Coral Reef Ecosystem	*S. crumenopthalmus* - akule	N.A.	N.A.	N.A.	389,844
	D. macarellus - opelu	N.A.	N.A.	N.A.	181,473
	Lutjanus kasmira - ta'ape	N.A.	N.A.	N.A.	N.A.
	L. fulvus - to'au	N.A.	N.A.	N.A.	N.A.
	Parupeneus porphyreus - kumu	N.A.	N.A.	N.A.	N.A.
	Cephalopholis argus - roi	N.A.	N.A.	N.A.	N.A.
	Acanthuridae - surgeonfish	N.A.	N.A.	N.A.	78,076
	Carangidae - jacks	N.A.	N.A.	N.A.	42,340
	Carcharhinidae - reef sharks	N.A.	N.A.	N.A.	2,500
	Crustaceans - crabs	N.A.	N.A.	N.A.	21,237
	Holocentridae - squirrelfish	N.A.	N.A.	N.A.	48,637
	Kyphosidae - rudderfish	N.A.	N.A.	N.A.	13,336
	Labridae - wrasse	N.A.	N.A.	N.A.	7,175
	Lethrinidae - emperors	N.A.	N.A.	N.A.	2,808
	Lutjanidae - snappers	N.A.	N.A.	N.A.	39,333
	Mollusk - snails, octopus, etc.	N.A.	N.A.	N.A.	30,658
	Mugilidae - mullets	N.A.	N.A.	N.A.	4,834
	Mullidae - goatfish	N.A.	N.A.	N.A.	61,184
	Scaridae - parrotfish	N.A.	N.A.	N.A.	33,902
	Serranidae - groupers	N.A.	N.A.	N.A.	1,327
	All other CREMUS combined	N.A.	N.A.	N.A.	13,823

Notes:
* MHI Deep 7 bottomfish is still ongoing for Fishing Year 2017-2018; data as of 08/31/2017.
*******Cheilinus undulatus*** and *Bolbometopon muricatum* are species not present in Hawaii.

The catch shown in Table 51 takes the average of the recent three years as recommended by the Council at its 160th meeting to avoid large fluctuations in catch due to data quality and outliers. "N.A.F." indicates no active fisheries as of date.

1.11 BEST SCIENTIFIC INFORMATION AVAILABLE

1.11.1 Main Hawaiian Island Deep 7 Bottomfish Fishery

1.11.1.1 Stock Assessment Benchmark

In 2011, NOAA's Pacific Islands Fisheries Science Center (PIFSC) completed a stock assessment for the MHI Deep 7 bottomfish fishery (2011 stock assessment) using data through 2010 (Brodziak *et al*., 2011). The 2011 stock assessment used similar commercial fishery data as in a 2008 assessment update (Brodziak *et al*., 2009), but includes a modified treatment of unreported catch and catch per unit effort (CPUE) standardization, as well as new research information on the likely life history characteristics of bottomfish (A. Andrews, PIFSC, unpublished 2010 research) in response to recommendations from the Western Pacific Stock Assessment Review (WPSAR) of the 2008 update (Stokes, 2009). Additionally, while the 2008 assessment considered the entire assemblage of Hawaii BMUS on an archipelagic basis (NWHI and MHI), the 2010 assessment focused solely on the Deep 7 bottomfish stock complex in the MHI.

To address the unreported catch issue, the 2011 assessment included four scenarios of unreported catch developed from available information. The four scenarios are labeled in order of magnitude from the highest (Scenario 1) to the lowest (Scenario 4) estimates of unreported catch.

- <u>Catch Scenario 1</u>: Unreported catch is two times commercial reported catch
- <u>Catch Scenario 2</u>: Unreported catch equals the commercial reported catch
- <u>Catch Scenario 3</u>: Unreported catch is one-fifth the commercial reported catch
- <u>Catch Scenario 4</u>: There is no unreported catch

According to the 2011 assessment the Catch Scenario 2 is the baseline (i.e., most plausible scenario) because it used the best available information on unreported to reported catch ratios estimated for individual MHI Deep 7 bottomfish species.

To determine the appropriate CPUE, the 2011 assessment included three scenarios to represent changes in fishing power of the fleet that targets Deep 7 bottomfish for commercial catch. CPUE is used in stock assessments as an index of relative stock abundance. Standardizing CPUE from different anglers over different areas and over many years helps to minimize the effects that could bias CPUE as an index of stock abundance.

- <u>CPUE Scenario 1</u>: Negligible change in bottomfish fishing power through time.
- <u>CPUE Scenario 2</u>: Moderate change in bottomfish fishing power through time. Specifically, this scenario assumed that: (i) there was no change in fishing power during 1949-1970; (ii) fishing power increased at a rate of 0.25 percent per year during 1971-1980; fishing power increased at a rate of 0.5 percent per year during 1981-1990; (iii) fishing power increased at a rate of 0.25 percent per year during 1991-2000; and (iv) fishing power did not change during 2001-2010.
- <u>CPUE Scenario 3</u>: Substantial change in bottomfish fishing power through time. Specifically, this scenario assumed that a substantial change in fishing power scenario

had occurred since the 1950s with an average increase in fishing power of roughly 1.2 percent per year.

According to the 2011 assessment, CPUE Scenario 1 is the baseline (i.e., most plausible scenario) because it represented the best scientific information about the efficiency of the Deep 7 bottomfish fishing fleet through time, and because it did not include ad hoc assumptions about changes in fishing power for the deep handline fishery that has traditionally harvested the Deep 7 bottomfish complex.

Based on the Catch 2/CPUE 1 scenario combination, the 2011 assessment estimates a maximum sustainable yield (MSY) of 417,000 lbs. for the MHI Deep 7 bottomfish stock complex. The 2011 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 and at five percent intervals (Table 19.1 in Brodziak *et al*., 2011). Under the Catch 2/CPUE 1 scenario combination, the catch limit associated with a 50 percent probability of overfishing is 383,000 lbs. of MHI Deep 7 bottomfish. Therefore, while the long-term MSY for the fishery is 417,000 lbs., the OFL for fishery is 383,000 lbs.

1.11.1.1.1 Findings of an Independent Peer Review

In January 2011, PIFSC contracted the Center for Independent Experts (CIE) to provide three independent experts to review a draft of the 2011 stock assessment and prepare a report of their independent findings and recommendations, and whether the 2011 stock assessment is the best scientific information available for management purposes. In general, the CIE review panel found that the 2011 stock assessment was scientifically sound, and applied appropriate modeling approaches and methods given data limitations. In addition, each reviewer provided recommendations on how to improve the next assessment particularly with respect to providing credible CPUE standardization. The reports of the CIE reviewers are available on the PIFSC website at http://www.pifsc.noaa.gov/do/peer_reviews/.

1.11.1.2 Stock Assessment Updates

In 2014, the PIFSC completed a draft 2014 stock assessment update for the MHI Deep 7 bottomfish fishery (2014 stock assessment), using data through fishing year 2013 (Brodziak *et al*., 2014). The 2014 stock assessment update uses the previous 2011 stock assessment's methods for data analysis, modeling, and stock projections, with one improvement--it included the State of Hawaii's CML data as a variable to standardize CPUE over time. The State began issuing CMLs uniquely and consistently to individuals through time starting in 1994. Therefore, beginning in 1994 the CML number assigned to an individual has remained the same. The 2014 stock assessment included individual CMLs in the CPUE standardization for that year onward. This improvement is highly significant, resulting in a two-fold increase in the explanatory power (R^2) of the CPUE standardization and a substantial decrease in the Akaike information criterion value of the CPUE standardization, which now explains over 50% of the variation in observed CPUE over time. Additionally, in the three additional years (2011-2013) covered by the 2014 assessment, the biomass of the Deep 7 species and the exploitation rate were about the same as in the preceding three years. Therefore, the updated estimates of the values for management (i.e., MSY, OFL, probability of overfishing etc.) are not a result of any significant change in biomass or exploitation rate, but are due to better estimation of the values provided by the previous assessment.

Based on the revised CPUE standardization method and three years of additional catch data, the 2014 stock assessment update re-estimates MSY to be 415,000 lbs., which is similar to the previous MSY estimate of 417,000 lbs. reported in the 2011 stock assessment. The 2014 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 and at five percent intervals (Table 15 in Brodziak *et al*., 2014). Based on a maximum potential harvest of 325,000 lb. of MHI Deep 7 bottomfish in the then-ongoing 2013-14 fishing year, the 2014 stock assessment estimated an OFL of 316,000 lbs., which is 67,000 lbs. less than the OFL estimate in the 2011 stock assessment. These updated estimates of MSY and OFL are not the result of any significant change in biomass or exploitation rate, but are due to better estimations resulting from the revised CPUE standardization method.

1.11.1.2.1 Findings of an Independent Peer Review

In December 2014, PIFSC again contracted the CIE to provide three independent experts to review the 2014 stock assessment and prepare a report of their independent findings and recommendations, and to assist NMFS in determining whether the 2014 stock assessment is the best scientific information available for management purposes. In summary, the CIE panel found that including individual CML data as a variable to standardize CPUE over time was an improvement over the method used in the 2011 stock assessment. However, the CIE panel had strong reservations regarding the quality of input catch data and CPUE index of abundance used in both the 2011 and 2014 stock assessments. Specifically, the panel raised concern about the historical pre-1990 data for CPUE calculation and estimates of unreported catch. Given the concerns with the incomplete effort information, the CIE panel concluded that the 2014 stock assessment had serious flaws that compromised its utility for management. In particular, the CIE panel noted that because the 2014 stock assessment was an update only, and required improvements in the index and the population model, the science reviewed in the 2014 stock assessment is not considered the best available. The reports of the CIE reviewers are available on NMFS website at http://www.st.nmfs.noaa.gov/science-quality-assurance/cie-peer-reviews/cie-review-2015.

1.11.1.3 Current Best Available Scientific Information

National Standard 2 requires that conservation and management measures be based on the best scientific information available, 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)).

On March 3, 2015, PIFSC outlined reasons why the fisheries data in the 2014 assessment produced results that the CIE panel advised was not ready for management application, and identified two ways in which the fisheries data can be improved for future application in the new CPUE standardization method.

1) Although catch per day fished is the best available CPUE that is available continuously over the whole time series, it may not be the best available over the most recent time series. If the time series is to be split with CPUE issues addressed differently before and after the split, one could also analyze and include detailed effort data that has been collected only for the last dozen years. This data could strongly influence recent trends. This was not seen by PIFSC as work that could be done as a simple update in 2014, because it is a complex undertaking.

   The use of CPUE defined as catch per day fished is subject to great criticism, and one way to address this is by using details on hours and numbers of lines and hooks used by fishermen over the last dozen years. Only inexplicit, undescribed differences among fishermen linked through time were applied to the recent stanza in the 2014 CPUE standardization. Using the recent effort detail would still allow differences between individual fishermen to be standardized, and also allow changes in effort details through time to be addressed. Both were factors of great concern to the reviewers. Differences among areas and seasons and other such factors that can be applied throughout the whole time series have remained part of the CPUE standardization in both 2011 and 2014.

2) Further efforts could be made to apply the CPUE standardization to account for differences among fishermen to more data using various exploratory methods and other data sets. The 2014 assessment overlooked a compilation of confidential non-electronic records held by the State of Hawaii that may help to link fisher's identities back through an earlier stanza of time.

Although the CIE panel noted the improvement in catch rate standardization in the 2014 stock assessment compared to 2011, it had strong reservations regarding the input catch data in both stock assessments, However, PIFSC cannot improve the assessment for MHI Deep 7 bottomfish in the ways described above in short order because it is a complex undertaking. Although catch per day fished may not be the best available CPUE data that can be used in the superior split-stanza CPUE standardization (i.e. after 1994), it is the best available CPUE data that is available over the entire time series, and thus appropriate for use in the 2011 assessment approach, which does not utilize a split-stanza CPUE standardization approach. Therefore, NMFS believes that a much simpler update of the 2011 assessment using data from the three most recent years available (i.e., 2011, 2012 and 2013) provides the best scientific information available for management. Applying this updated data, NMFS revised the MSY for MHI Deep 7 bottomfish from 417,000 lb. to 404,000 lb. and the OFL from 383,000 lb. 352,000 lb. These values do not reflect a drastic change in stock status from the information considered by the Council, and the proposed ACL of 346,000 lb. remains below the revised OFL of 352,000 lb.

1.11.2 Non-Deep 7 Bottomfish Fishery

1.11.2.1 Stock Assessment Benchmark

There is no benchmark stock assessment for the non-Deep 7 bottomfish. A previous attempt to determine sustainability of the non-Deep 7 bottomfish stock was done in conjunction with the assessment of the MHI Deep 7 bottomfish stocks. In 2011, NMFS Pacific Islands Fisheries Science Center completed a stock assessment for the Deep 7 bottomfish stock complex using data from 1949-2010 and produced stock projection results of a range of commercial catches of Deep 7 bottomfish that would produce probabilities of overfishing ranging from zero percent to 100 percent, and at five-percent intervals in fishing year 2011-12, and in 2012-13 (Brodziak *et al*., 2011, Table 19.1 and shown in Appendix C). The 2011 stock assessment used similar commercial fishery data as in the previous 2008 stock assessment that assessed the entire Hawaii multi-species bottomfish stock complex as a whole (Brodziak *et al*., 2009); however, the 2011 assessment includes a modified treatment of unreported catch and CPUE standardization, as well as new research information on the likely life history characteristics of Deep 7 bottomfish (A. Andrews, PIFSC, unpublished 2010 research).

According to the 2011 bottomfish stock assessment, the Catch 2/CPUE 1 scenario combination represents the best approximation (with a 40 percent probability) of the true state of the bottomfish fishery and Deep 7 bottomfish population dynamics. Under the Catch 2/CPUE 1 scenario combination, the long-term MSY of the MHI Deep 7 bottomfish stock complex is estimated to be 417,000 lbs. The assessment model also estimates that the commercial catch associated with a 50 percent probability of overfishing the MHI Deep 7 bottomfish complex in fishing year 2011-12 and again in fishing year 2012-13 is 383,000 lbs. Therefore, while the long-term MSY for the Deep 7 bottomfish fishery is 417,000 lb., the overfishing limit (OFL) for the 2011-12 and 2012-13 fishing years is estimated to be 383,000 lbs.

The 2011 MHI Deep 7 bottomfish stock assessment does not include an evaluation of stock status or the risk of overfishing for any of the remaining BMUS in the MHI. Therefore, biological reference points, including estimates of MSY and OFL for the MHI non-Deep 7 bottomfish are unknown. However, the stock assessment projection results for the MHI Deep 7 bottomfish stock complex can be used to develop an OFL proxy for the MHI non-Deep 7 bottomfish stock complex, and a range of commercial non-Deep 7 bottomfish catches that would produce probabilities of overfishing ranging from zero percent to 100 percent. This approach relies on the assumption that population dynamics, catchability and other parameters of the non-Deep 7 bottomfish are similar in relative scale to the Deep 7 bottomfish (Brodziak, pers. com. March 31, 2011). In general, MHI non-Deep 7 bottomfish are coral reef associated species and are more productive compared to MHI Deep 7 bottomfish. However, non-Deep 7 bottomfish are also harvested by a greater range of gear methods, which results in levels, and rates of exploitation that have not been assessed quantitatively or qualitatively in any previous stock assessment.

While a separate stock assessment for MHI non-Deep 7 bottomfish is the preferred approach, until one is produced, estimating a proxy for OFL and probabilities of overfishing for this stock complex based on projection results for MHI Deep 7 bottomfish is an appropriate approach given the fact that only catch data are available for the non-Deep 7 stock complex. Additionally, this catch data indicate that reported commercial catches of MHI Deep 7 bottomfish in proportion to the total reported commercial catches of all MHI bottomfish (Deep 7 + non-Deep 7) are relatively stable over time as reported in Tables 5 (estimates of total Deep 7 catches) and Table 6 (estimates of total bottomfish catches) contained in Brodziak *et al*. (2011). Therefore, reported commercial catches of MHI non-Deep 7 bottomfish in proportion to total reported commercial catches of all MHI bottomfish are also stable over time.

Table 52 summarizes the average proportion of the reported commercial catches (C) of MHI Deep 7 bottomfish relative to the total reported commercial catches of all MHI bottomfish for three time periods: (1) 1949-2010; (2) 2000-2009; and 2008-2010 as presented in Tables 5 and 6 in Brodziak *et al*. (2011). The proportion of MHI Deep 7 catch (PDEEP7) to the total MHI bottomfish catch is also provided and is calculated using the following equation:

PDEEP7(t) = CDEEP7(t) / C Total BMUS(t)

These three time periods were chosen because they reflect the nature of the Hawaii bottomfish fishery over (1) the entire available catch history; (2) the recent decade; and (3) three recent years when the fishery operated under a catch limit system. The results summarized in Table 52 clearly demonstrate that the proportion of Deep 7 to the total reported commercial catches of all MHI bottomfish (Deep 7 + non-Deep 7) has been relatively stable over time with ranges from 67 percent to 72 percent. Conversely, this demonstrates the proportion of non-Deep 7 bottomfish to the total MHI bottomfish catch ranged from 33 percent to 28 percent.

Table 52. Proportion of reported commercial catches of MHI Deep 7 and total reported commercial MHI bottomfish catch over time under Catch 2/CPUE 1 scenario.

	t = 1949-2010	t = 2000-2009	t = 2008-2010
Catch of Deep 7 bottomfish[1]	281.3	234.3	221.5
Catch of Total BMUS[2]	422.1	325.3	330.7
Proportion of Deep 7 (P_{DEEP7})	0.666	0.720	0.700

Notes:
[1] Source: Table 5 in Brodziak *et al*., (2011).
[2] Source: Table 6 in Brodziak *et al*., (2011).

Because two Hawaii BMUS, ta‘ape *(Lutjanus kasmira)* and kahala (*Seriola dumerili),* are specifically excluded from the NMFS Hawaii bottomfish stock assessment parameters, their catch information is not included in the total bottomfish estimates used in Table 6 of Brodziak *et al*. (2011).

To estimate an OFL proxy for the MHI non-Deep 7 bottomfish stock complex and a range of commercial non-Deep 7 bottomfish catches that would produce probabilities of overfishing ranging from zero percent to 100 percent, the commercial catch values for MHI Deep 7 bottomfish associated with Catch 2/ CPUE Scenario 1 as presented in Table 19.1 of Brodziak *et al*., (2011), and shown in Appendix C can be divided by the P_{DEEP7} values in Table 52 above. The results of this calculation will derive the total commercial catch equivalent of all MHI bottomfish (Deep 7 + non-Deep 7) and the corresponding probabilities of overfishing all MHI bottomfish.

To derive the level of catch that would produce the corresponding probability of overfishing for MHI non-Deep 7 bottomfish (excluding ta‘ape and kahala), the level of catch for MHI Deep 7 bottomfish is simply subtracted from the level of catch for all MHI bottomfish.

Table 53 summarizes the results of this calculation for the time period 1949-2010. This time period is identical to the time period used to produce stock projection results for the Deep 7 stock complex and is the baseline for impact analyses.

Table 53. Commercial catch (in1000 pounds) of MHI Deep 7 BMUS, MHI non-Deep 7 BMUS and all MHI BMUS combined that would produce probabilities of overfishing from 0 through 99% based on 1949-2010 catch data (P_{DEEP7} = 0.666).

Probability of Overfishing[1]	Catch of MHI Deep 7 BMUS[1]	Catch of All MHI BMUS *(Deep 7 + non-Deep 7)*[2]	Catch of MHI non-Deep 7 BMUS[2]
0	11	17	6
5	147	221	74
10	197	296	99
15	229	344	115
20	255	386	131
25	277	415	138
30	299	449	150
35	319	479	160
40	341	512	171
45	361	542	181
50	383	575	192
55	407	611	204
60	429	644	215
65	455	683	228
70	481	722	241
75	513	779	266
80	549	824	275
85	597	896	299
90	665	998	333
95	783	1176	393
99	1001	1503	502

Notes:
[1] Source: Table 19.1 in Brodziak *et al*., (2011)
[2] Excludes Hawaii BMUS ta‘ape *(Lutjanus kasmira)* and kahala (*Seriola dumerili*).

Based on

Table 53 above, the catch limit associated with a 50 percent probability of overfishing the MHI Deep 7 bottomfish complex in fishing year 2011-12 and again in fishing year 2012-13 is 383,000 lbs. The catch limit associated with a 50 percent probability of overfishing the MHI non-Deep 7 bottomfish complex in fishing year 2012 and again in 2013 was 192,000 lbs. and is the OFL proxy. These estimates will continue to apply in future fishing years until a new Deep 7 stock assessment update and associated stock projection analysis is conducted or a separate non-Deep 7 assessment is prepared.

1.11.2.2 Stock Assessment Updates

The initial method described above was abandoned in 2014. Estimates of MSY and OFL for non-Deep 7 bottomfish in the MHI are based on a modeling approach that uses catch data from local resource management agencies as described in Section 1.2; together with a measure of population growth (*r*), carrying capacity (*k*), and biomass data from NMFS PIFSC underwater fish census surveys (Williams, 2010). This model, termed the "Biomass Augmented Catch-MSY" model is described in detail in Sabater and Kleiber (2014). In summary, the model creates annual biomass projections from a set of *r* and *k* combinations that would not result in biomass that would exceed the carrying capacity or the stock being depleted. The assumption behind the biomass can be informed by augmenting the model with an independent source of biomass information.

The Biomass Augmented Catch-MSY model is based on the Catch-MSY model developed by Martell and Froese (2013), but differs in that it incorporates biomass data. Application of the model provides the very first model-based estimate of MSY for MHI non-Deep 7 bottomfish. In addition to estimates of MSY, the Biomass Augmented Catch-MSY model also generates a range of catches that if realized, would result in a probability of exceeding MSY ranging from five to 50 percent.

Because of the large number of possible combinations of *r* and *k* values available to estimate MSY using the Biomass Augmented Catch-MSY model, the model explored two methods to define the most meaningful and most likely (most plausible) range of *r* and *k* combinations. Method A allows for only a very narrow range of starting *r* and *k* values, while method B allows for a broad range of starting *r* and *k* values, with each method providing different MSY estimates and associated probability of overfishing projections. In reviewing the two methods, the SSC at its 114th meeting held March 11-13, 2014, determined the resulting MSY estimates from method B be used for management decisions because this method provides a more complete range of most likely *r* and *k* combinations compared to method A. The 114th SSC also found that method B also yielded *r* and *k* density plots that generally correspond better to the estimates of MSY than the method A approach.

Based on the method B approach, the Biomass Augmented Catch-MSY model estimates MSY for MHI non-Deep 7 bottomfish to be 265,000 lbs. However, catch projection results generated from the model estimates the level of catch associated with a 50 percent probability of exceeding MSY to be 259,200 lbs. Consistent with National Standard 1 guidelines (74 FR 3178, January 9, 2011), the Council at its 160th meeting, set OFL for MHI non-Deep 7 bottomfish equal to the level of catch associated with a 50 percent probability of exceeding MSY.

In February 2017, PIFSC released the final species level assessment for the main Hawaiian Islands (Nadon, 2017). This assessment covers 27 species of reef fishes, three of which are non-Deep 7 bottomfish: *Caranx ignobilis*, *Aprion virescens*, and *Lutjanus kasmira*.

This assessment utilized a different approach compared to the existing model used for the FY2015-2018 specification. It used life history information and a length-based approach to obtain stock status based on spawning potential ratio (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*), spawning potential ratios (SPR), SPR-based sustainable fishing rates (F30; F resulting in SPR = 30%), and catch levels corresponding to these sustainable rates (C30). 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 C30, was obtained by combining F30 estimates with current population biomass estimates derived directly from diver surveys or indirectly from the total catch. The overfishing limits (OFL) corresponding to a 50% risk of overfishing was defined as the median of the C30 distribution.

These assessments have undergone substantial peer review starting with the CIE review on September 8-11, 2015 (Dichmont, 2015; Pilling, 2015; Stokes, 2015). The assessment author addressed the CIE review comments and recommendations and developed a stock assessment report that was reviewed by the WPSAR panel from August 29, 2016 to September 2, 2016 (Choat, 2016; Franklin, 2016a; Franklin, 2016b; Stokes, 2016). The assessment author revised the draft assessment addressing the WPSAR panel comments and recommendation and presented the final stock assessment document at the 125th and 169th meeting of the SSC and Council, respectively. These assessments are considered the best scientific information available for these species.

1.11.3 Coral Reef Fishery

1.11.3.1 Stock Assessment Benchmark

Coral Reef Ecosystem Management Unit Species Complex-Level Assessment

The first attempt to use a model-based approach in assessing the coral reef MUS complexes was done in 2014 using a biomass-based population dynamics model (Sabater and Kleiber 2014) for the purpose of improving the ACL specification for these stocks. This model was based on the original Martell and Froese (2012) model but was augmented with biomass information to relax the assumption behind carrying capacity. It estimates MSY based on a range of rate of population growth (*r*) and carrying capacity (*k*) values. The best available information for the complex level coral reef stock assessment is as follows:

Input data: The catch data was derived commercial marine license reports.

Model: Biomass Augmented Catch MSY approach based on the original catch-MSY model (Martell and Froese, 2012; Sabater and Kleiber, 2014).

Fishery independent source for biomass: biomass density from the Rapid Assessment and Monitoring Program of NMFS-CREP was expanded to the hard bottom habitat from 0-30 m (Williams, 2010).

This model had undergone a CIE review in 2014 (Cook, 2014; Haddon, 2014; Jones, 2014). This was the basis for the P* analysis that determined the risk levels to specify ABCs. This model was used for the multi-year specification for fishing year 2015-2018.

Coral Reef Ecosystem Management Unit Species Species-Level Assessment

In February 2017, PIFSC released the final species level assessment for the main Hawaiian Islands (Nadon, 2017). This assessment covers 27 species of reef fishes, 24 of which are CREMUS: *Acanthurus blochii*, *Acanthurus dussumieri*, *Naso brevirostris*, *Naso hexacanthus*, *Naso lituratus*, *Naso unicornis*, *Carangoides orthogrammus*, *Caranx melampygus*, *Lutjanus fulvus*, *Mulloidichthys flavolineatus*, *Mulloidichthys pfluegeri*, *Mulloidichthys vanicolensis*, *Parupeneus cyclostomus*, *Parupeneus insularis*, *Parupeneus porphyreus*, *Calotomus carolinus*, *Chlorurus perspecillatus*, *Chlorurus spilurus*, *Scarus dubius*, *Scarus psittacus*, *Scarus rubroviolaceus*, *Cephalopholis argus*, *Monotaxis grandoculis*, and *Myripristis berndti*.

This assessment utilized a different approach compared to the existing model used for the FY2015-2018 specification. It used life history information and a length-based approach to obtain stock status based on spawning potential ratio (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), spawning potential ratios (SPR), SPR-based sustainable fishing rates (F30; F resulting in SPR = 30%), and catch levels corresponding to these sustainable rates (C30). 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 C30, was obtained by combining F30 estimates with current population biomass estimates derived directly from diver surveys or indirectly from the total catch. The overfishing limits (OFL) corresponding to a 50% risk of overfishing was defined as the median of the C30 distribution.

These assessments have undergone substantial peer review starting with the CIE review on September 8-11, 2015 (Dichmont, 2015; Pilling, 2015; Stokes, 2015). The assessment author addressed the CIE review comments and recommendations and developed a stock assessment report that was reviewed by the WPSAR panel from August 29, 2016 to September 2, 2016 (Choat, 2016; Franklin, 2016a; Franklin, 2016b; Stokes, 2016). The assessment author revised the draft assessment addressing the WPSAR panel comments and recommendation and presented the final stock assessment document at the 125th and 169th meeting of the SSC and Council, respectively. These assessments are considered the best scientific information available for these species.

1.11.3.2 Stock Assessment Updates

No updates available for the coral reef MUS complex.

1.11.3.3 Other Information Available

Approximately every five years PIFSC administers a socioeconomic survey to small boat fishermen in Hawaii. This survey consists of about 60 questions regarding a variety of topics, including fishing experiences, market participation, vessels and gear, demographics and household income, and fishermen perspectives. The survey requests participants to identify which MUS they primarily targeted during the previous 12 months, by percentage of trips. Full reports of these surveys can be found at the PIFSC Socioeconomics webpage (Hospital and Beavers, 2011).

PIFSC and the Council conducted a workshop with various stakeholders in CNMI to identify factors and quantify uncertainties associated with the social, economic, ecological, and management of the coral reef fisheries (Sievanen and McCaskey, PIFSC internal report). This was the basis for the SEEM analysis that determined the risk levels to specify ACLs for all areas.

1.11.4 Crustacean Fishery

1.11.4.1 Stock Assessment Benchmark

Spiny Lobsters: There is no benchmark stock assessment for any of the crustacean MUS. The first attempt to use a model-based approach in assessing the crustacean MUS complexes, particularly spiny lobsters, was done in 2014 using a biomass-based population dynamics model (Sabater and Kleiber 2014) for the purpose of improving the ACL specification for these stocks. This model was based on the original Martell and Froese (2012) model but was augmented with biomass information to relax the assumption behind carrying capacity. It estimates MSY based on a range of rate of population growth (*r*) and carrying capacity (K) values. The best available information for the coral reef stock assessment is as follows:

Input data: The catch data was derived from the commercial marine license report.

Model: Biomass Augmented Catch MSY approach based on the original catch-MSY model (Martell and Froese 2012; Sabater and Kleiber 2014).

Fishery independent source for biomass: There is no fishery independent data collection for crustaceans

This model had undergone a CIE review in 2014 (Cook, 2014; Haddon, 2014; Jones, 2014). This was the basis for the P* analysis that determined the risk levels to specify ABCs.

Slipper Lobsters: There has been no attempt to conduct an assessment of the slipper lobster stock. The best attempt to come up with a yield estimate was to use the 75th percentile of the entire catch time series. This follows recommendations from the ORCS Working Group for data poor species (Berkson *et al*., 2011).

Deep-water Shrimp: The deep water shrimp (*Heterocarpus laevigatus* and *H. ensifer*) initial resource assessment was conducted in the late 1980s by Ralston and Tagami (1988). 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 stock assessment model was developed in 2014 in an attempt to understand and determine the status of the Kona crab stock in the main Hawaiian Islands (Thomas *et al.*, 2015). This assessment utilized a non-equilibrium generalized production model (using the Stock-Production Model Incorporating Covariate –ASPIC statistical routine) to estimate parameters needed to determine stock status. Based on this, the Kona crab stock is overfished (possibly rebuilding) but not experiencing overfishing.

This assessment had undergone a CIE desktop review in December 2015 (Hall, 2015). The review concluded that the assessment had utilized the appropriate model and used the data and assumptions correctly making the assessment best available. However, the reviewer also cautioned that there are large uncertainties associated with the results which could change dramatically with the changes in the non-commercial catch assumptions and effects of the State of Hawaii's female release regulations. PIFSC agreed that further work is needed to provide advice on the current status of the population in more recent years. This was included in the list of stocks that PIFSC will conduct a benchmark assessment on in the future. To date, the best available information is based on the 75th percentile of the entire catch time series as a proxy for sustainable yield levels.

1.11.4.2 Stock Assessment Updates

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

1.11.4.3 Best Scientific Information Available

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

- Spiny lobsters – Sabater and Kleiber (2014).
- Slipper lobsters – WPRFMC (2011) – cite non-fin-fish EA.
- Deepwater shrimp – Ralston and Tagami (1988).
- Kona crabs – Lennon *et al.*, (2015) – cite non-fin-fish EA.

1.12 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 on the basis of 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 in the coral reef and 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 and coral reef fish MUS complexes is defined to be the level of harvest equal to the ACL consistent with the goals and objectives of the Fishery Ecosystem Plans 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 F_{MSY}. There are situations when the long-term means around MSY are going to be lower than ACLs especially if the stock is known to be productive or relatively pristine or lightly fished. One can have catch levels and catch rates exceeding that of MSY over short-term enough to lower the biomass to a level around the estimated MSY and still not jeopardize the stock. This situation is true for the territory bottomfish multi-species complex.

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 54 summarizes the harvest extent and harvest capacity information for Hawaii in 2015

Table 54. Proportions of harvest extent and harvest capacity in the MHI.

Fishery	Management Unit Species	ACL	Catch	Harvest extent (%)	Harvest capacity (%)
Bottomfish	MHI Deep 7 stock complex	326,000	266,550	81.8	18.2
	MHI Non-Deep 7 stock complex	N.A.	127,265	N.A.	N.A.
Crustaceans	Deepwater shrimp	250,773	16,139	6.4	93.6
	Spiny lobster	15,000	6,617	44.1	55.9
	Slipper lobster	280	0	0.0	100.0

	Kona crab	N.A.	1,993	N.A.	N.A.
Precious coral	Auau channel-black coral	5,512	N.A.F.	N.A.	N.A.
	Makapuu bed-pink coral	2,205	N.A.F.	N.A.	N.A.
	Makapuu bed-bamboo coral	551	N.A.F.	N.A.	N.A.
	180 fathom bank-pink coral	489	N.A.F.	N.A.	N.A.
	180 fathom bank-bamboo coral	123	N.A.F.	N.A.	N.A.
	Brooks bank-pink coral	979	N.A.F.	N.A.	N.A.
	Brooks bank-bamboo coral	245	N.A.F.	N.A.	N.A.
	Kaena point bed-pink coral	148	N.A.F.	N.A.	N.A.
	Kaena point bed-bamboo coral	37	N.A.F.	N.A.	N.A.
	Keahole bed-pink coral	148	N.A.F.	N.A.	N.A.
	Keahole bed-bamboo coral	37	N.A.F.	N.A.	N.A.
	Precious coral in HI exploratory area	2,205	N.A.F.	N.A.	N.A.
Coral Reef Ecosystem	*S. crumenopthalmus*-akule	N.A.	389,844	N.A.	N.A.
	D. macarellus-opelu	N.A.	181,473	N.A.	N.A.
	Acanthuridae-surgeonfish	N.A.	78,076	N.A.	N.A.
	Carangidae-jacks	N.A.	42,340	N.A.	N.A.
	Carcharhinidae-reef sharks	N.A.	2,500	N.A.	N.A.
	Crustaceans-crabs	N.A.	21,237	N.A.	N.A.
	Holocentridae-squirrelfish	N.A.	48,637	N.A.	N.A.
	Kyphosidae - rudderfish	N.A.	13,336	N.A.	N.A.
	Labridae - wrasse	N.A.	7,175	N.A.	N.A.
	Lethrinidae - emperors	N.A.	2,808	N.A.	N.A.
	Lutjanidae-snappers	N.A.	39,333	N.A.	N.A.
	Mollusk-turbo snails, octopus, giant clam	N.A.	30,658	N.A.	N.A.
	Mugilidae-mullets	N.A.	4,834	N.A.	N.A.
	Mullidae-goatfish	N.A.	61,184	N.A.	N.A.
	Scaridae-parrotfish	N.A.	33,902	N.A.	N.A.
	Serranidae - groupers	N.A.	1,327	N.A.	N.A.
	All other CREMUS combined	N.A.	13,823	N.A.	N.A.

1.13 ADMINISTRATIVE AND REGULATORY ACTIONS

This summary describes management actions PIRO has taken since the April 2016 Joint FEP Plan Team meeting, as reported to the 166rd to 168th Western Pacific Fishery Management Council meetings held June 2016, October 2016, and March 2017.

April 7, 2016. Final 2015-16 Annual Catch Limits and Accountability Measures. **Main Hawaiian Islands Deep 7 Bottomfish**. NMFS specified an annual catch limit (ACL) of 326,000 lbs. for Deep 7 bottomfish in the main Hawaiian Islands (MHI) for the 2015-16 fishing year. As an accountability measure (AM), if the ACL is projected to be reached, NMFS would close the commercial and non-commercial fisheries for MHI Deep 7 bottomfish for the remainder of the fishing year. The ACL and AM specifications support the long-term sustainability of Hawaii bottomfish. The specifications were effective May 9, 2016.

April 21, 2016. NMFS announced that the Secretary of Commerce approved Amendment 4 to the Fishery Ecosystem Plan for the Hawaiian Archipelago. In Amendment 4, the Council revised the essential fish habitat and habitat areas of particular concern for 14 species of bottomfish and three species of seamount groundfish in the Hawaiian Archipelago. The action considers the best available scientific, commercial, and other information about the fisheries, and supports the long-term sustainability of fishery resources.

January 18, 2017. Final 2016-17 Annual Catch Limit and Accountability Measures. **Main Hawaiian Islands (MHI) Deep 7 Bottomfish**. In this final rule, NMFS specifies an annual catch limit (ACL) of 318,000 lbs. of Deep 7 bottomfish in the MHI for the 2016-17 fishing year. As an accountability measure (AM), if the ACL is projected to be reached, NOAA Fisheries would close the commercial and non-commercial fisheries for MHI Deep 7 bottomfish for the remainder of the fishing year. The ACL and AM support the long-term sustainability of Hawaii bottomfish. The final specifications are effective from February 17, 2017, through August 31, 2017.

January 18, 2017 (82 FR 5517). **Pacific Island 2016 Annual Catch Limits and Accountability Measures**. NMFS proposed annual catch limits (ACLs) for Pacific Island bottomfish, crustacean, precious coral, and coral reef ecosystem fisheries, and accountability measures (AMs) to correct or mitigate any overages of catch limits. The proposed ACLs and AMs would be effective for fishing year 2016. The fishing year for each fishery begins on January 1 and ends on December 31, except for precious coral fisheries, which begin July 1 and end on June 30 the following year. Although the 2016 fishing year has ended for most stocks, NMFS evaluates 2016 catches against the 2016 ACLs when data become available in mid-2017. The proposed ACLs and AMs support the long-term sustainability of fishery resources of the U.S. Pacific Islands. The comment period ended February 2, 2017.

January 23, 2017. **2017 NWHI lobster harvest guideline**. NMFS establishes the annual harvest guideline for the commercial lobster fishery in the Northwestern Hawaiian Islands for calendar year 2017 at zero lobsters.

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2 ECOSYSTEM CONSIDERATIONS

2.1 FISHERY ECOSYSTEM

2.1.1 Regional Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:

- ✓ American Samoa
- ✓ Guam
- ✓ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ✓ Pacific Remote Island Areas

Spatial Scale:

- ✓ Regional
- ☐ Archipelagic
- ☐ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods are described in detail elsewhere (http://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_15-07.pdf), but in brief 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 (http://www.fishbase.org), 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.

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) 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.

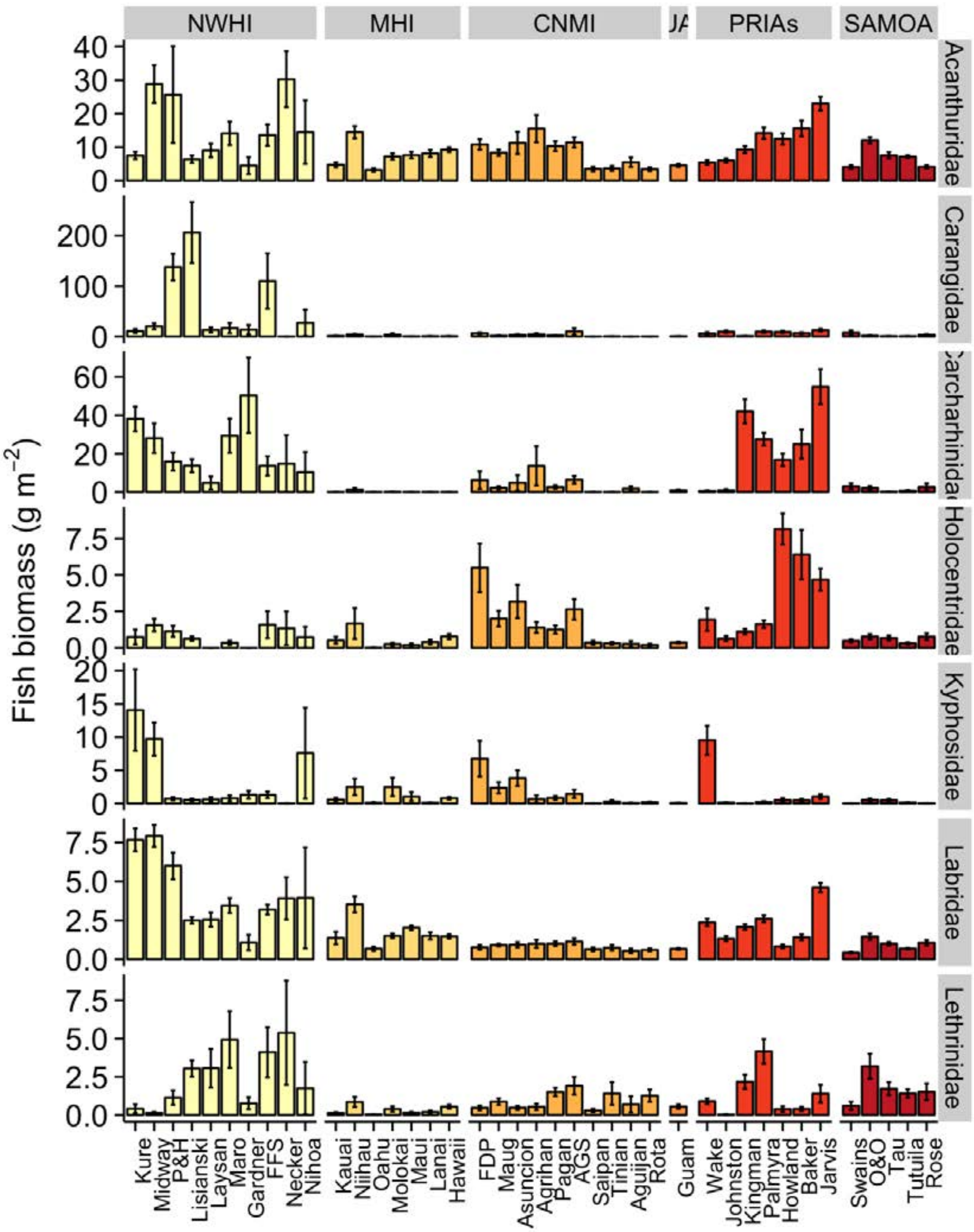
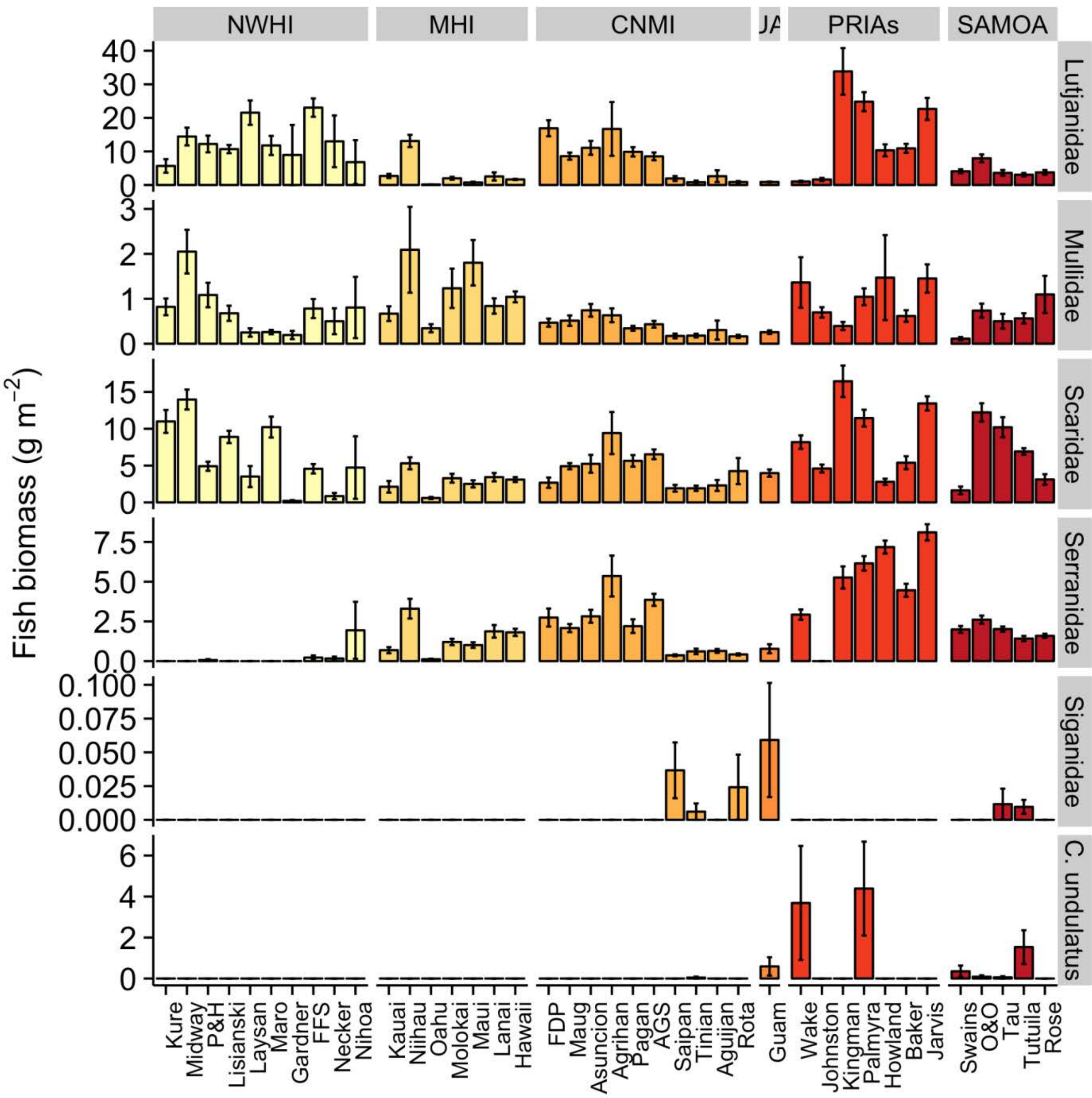


Figure 6. Mean fish biomass (g/m^2 ± standard error) of Coral Reef Management Unit Species (CREMUS) grouped by U.S. Pacific reef area from the years 2009-2015. Islands are ordered within region by latitude. Figure continued on next page.


NWHI
MHI
CNMI
JA
PRIAs
SAMOA
Lutjanidae
Mullidae
Scaridae
Serranidae
Siganidae
C. undulatus
Fish biomass (g m^{-2})
Kure
Midway
P&H
Lisianski
Laysan
Maro
Gardner
FFS
Necker
Nihoa
Kauai
Niihau
Oahu
Molokai
Maui
Lanai
Hawaii
FDP
Maug
Asuncion
Agrihan
Pagan
AGS
Saipan
Tinian
Aguijan
Rota
Guam
Wake
Johnston
Kingman
Palmyra
Howland
Baker
Jarvis
Swains
O&O
Tau
Tutuila
Rose

2.1.2 Main Hawaiian Islands Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem. Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1).

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) 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.

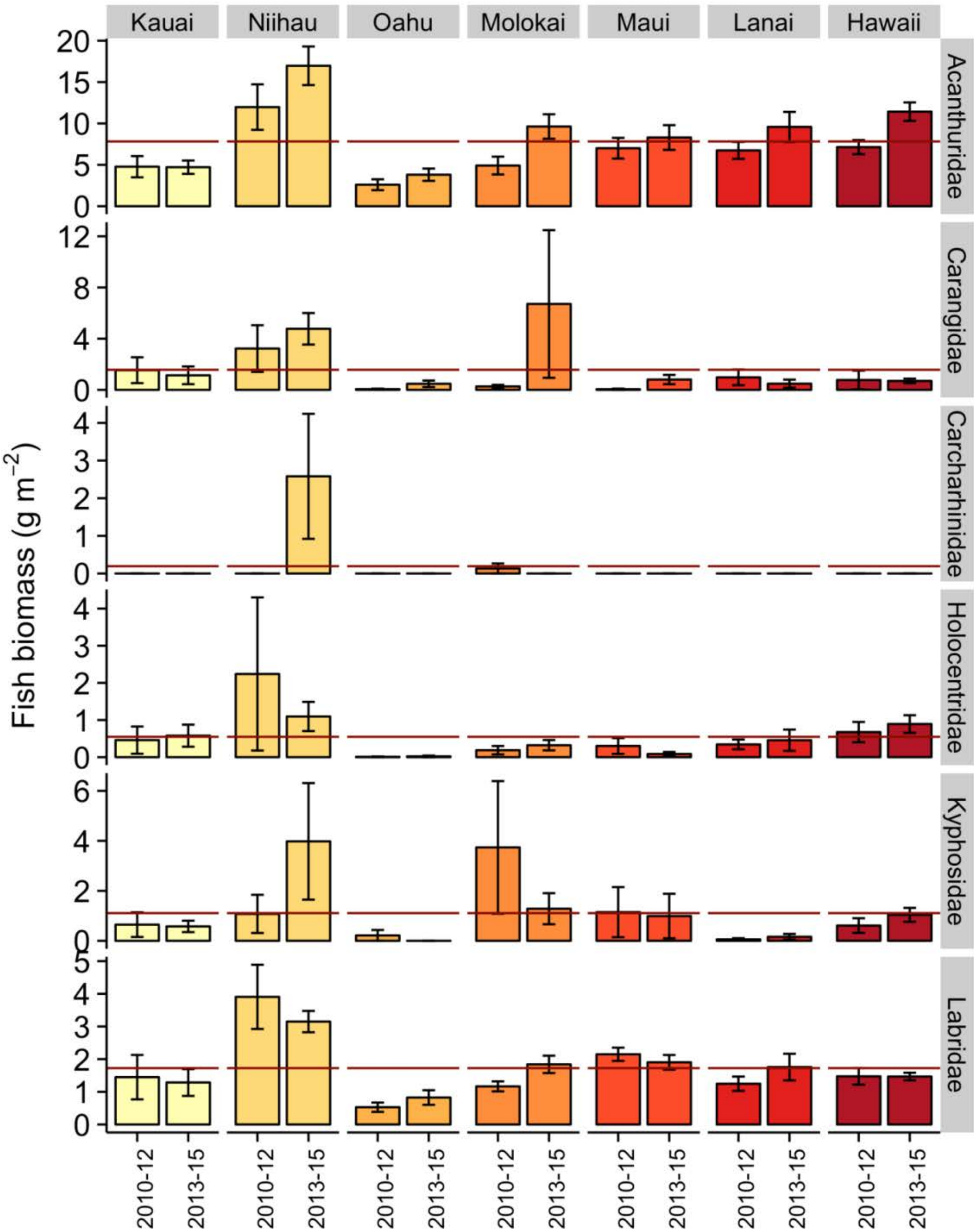
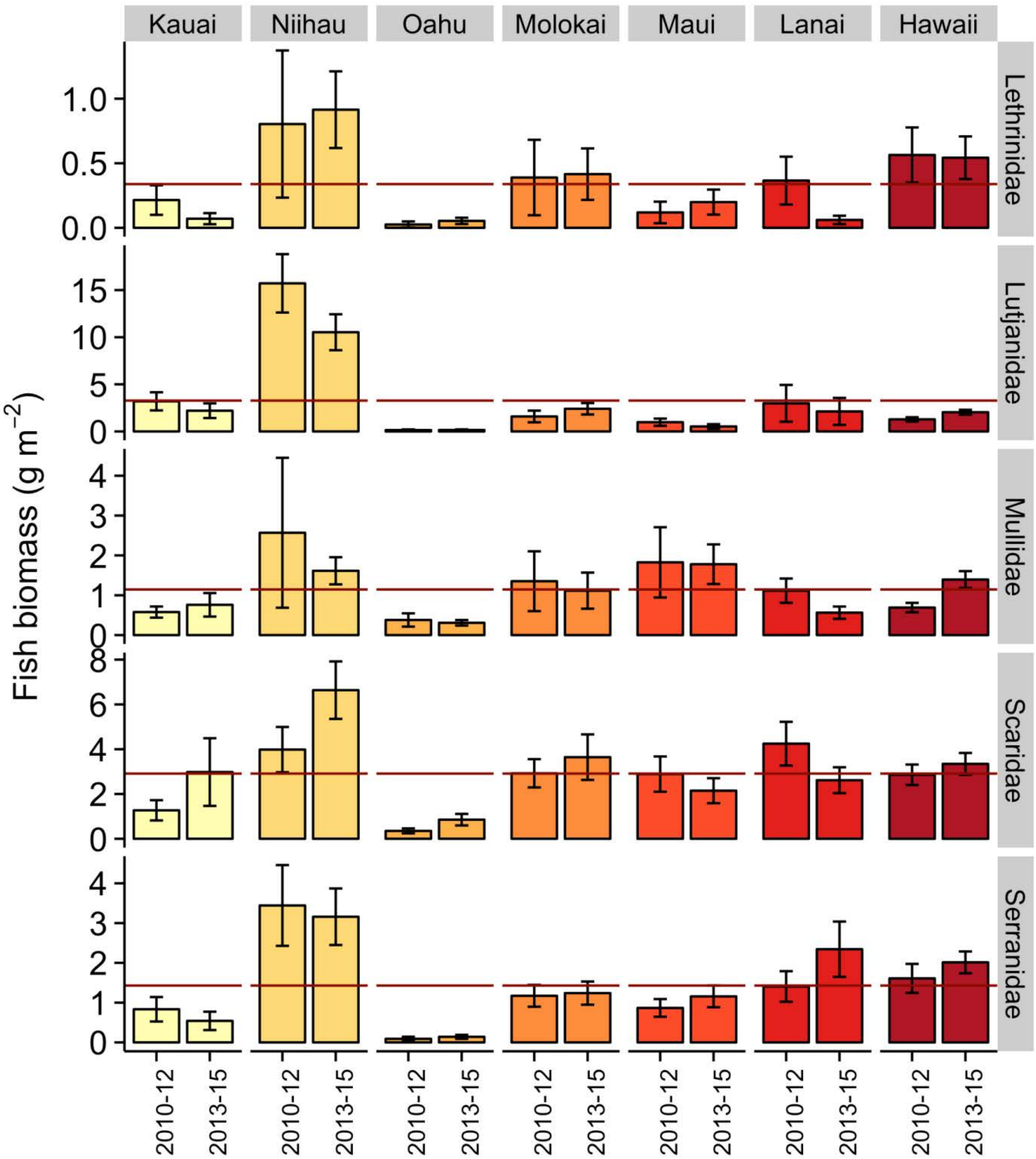


Figure 7. Mean fish biomass (g/m^2 ± standard error) of MHI CREMUS from the years 2009-2015. The MHI mean estimates are represented by the red line. Figure continued on next page.


Kauai
Niihau
Oahu
Molokai
Maui
Lanai
Hawaii
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
Fish biomass (g m^{-2})
2010-12
2013-15

2.1.3 Archipelagic Mean Fish Size

Description: 'Mean fish size' is the mean size of reef fishes >10 cm TL (i.e. excluding small fishes) derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:

- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:

- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:

- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem. Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Fishes smaller than 10 cm TL are excluded so that the fish assemblage measured more closely reflects fishes that are potentially fished, and so that mean sizes are not overly influenced by variability in space and time of recent recruitment.

Rationale: Mean size is important as it is widely used as an indicator of fishing pressure. A fishery can sometimes preferentially target large individuals, and can also the number of fishes reaching older (and larger) size classes. Large fishes contribute disproportionately to community fecundity and can have important ecological roles; for example, excavating bites by large parrotfishes probably have a longer lasting impact on reef benthos than bites by smaller fishes.

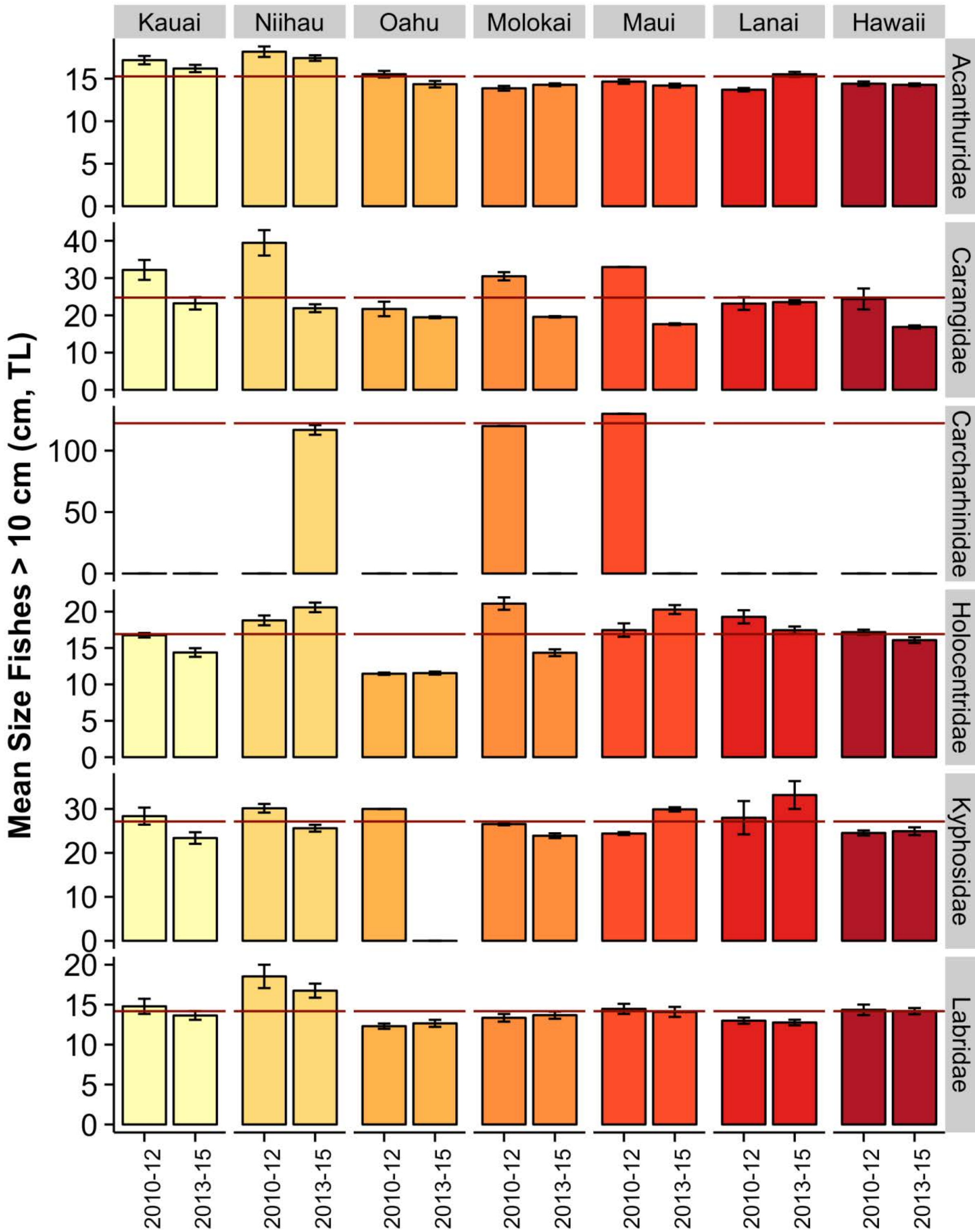
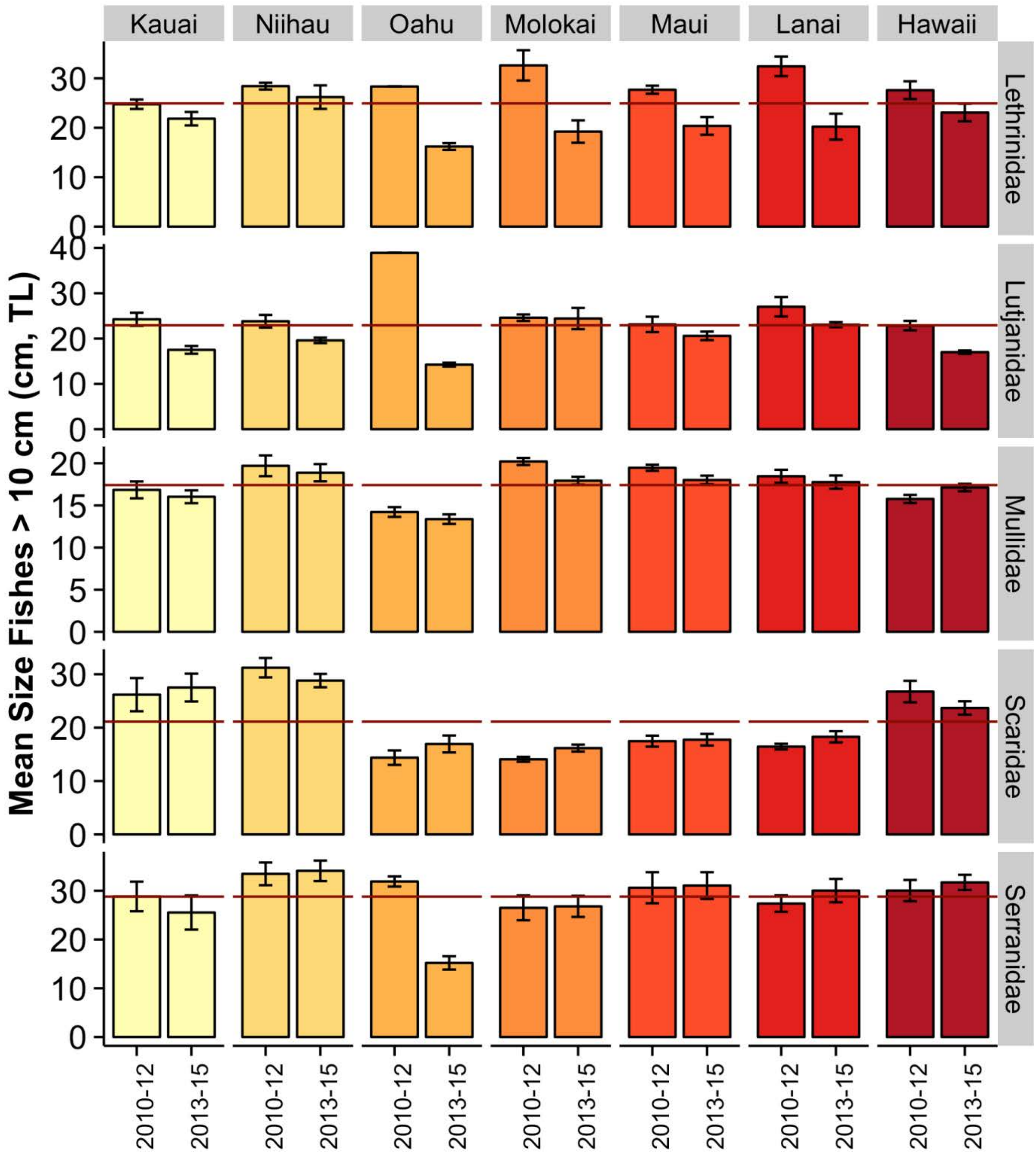


Figure 8. Mean fish size (cm, TL ± standard error) of MHI CREMUS from the years 2009-2015. The MHI mean estimates are plotted for reference (red line). Figure continued from previous page.


Kauai
Niihau
Oahu
Molokai
Maui
Lanai
Hawaii
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
Mean Size Fishes > 10 cm (cm, TL)
2010-12
2013-15

2.1.4 Reef Fish Population Estimates

Description: 'Reef fish population estimates' are calculated by multiplying mean biomass per unit area by estimated hardbottom area in a consistent habitat across all islands (specifically, the area of hardbottom forereef habitat in < 30 meters of water).

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ☐ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem. Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Those estimates are converted to population estimates by multiplying biomass (g/m^2) per island by the estimated area of hardbottom habitat <30 meters deep at the island, which is the survey domain for the monitoring program that biomass data comes from. Measures of estimated habitat area per island are derived from GIS bathymetry and NOAA Coral Reef Ecosystems Program habitat maps. Many reef fish taxa are present in other habitats than is surveyed by the program, and some taxa likely have the majority of their populations in deeper water. Additionally, fish counts have the potential to be biased by the nature of fish response to divers. Curious fishes, particularly in locations where divers are not perceived as a threat, will tend to be overestimated by visual survey, while skittish fishes will tend to be undercounted. It is also likely that numbers of jacks and sharks in some locations, such as the NWHI are overestimated by visual survey. Nevertheless, the data shown here are consistently gathered across space and time.

Rationale: These data have utility in understanding the size of populations from which fishery harvests are extracted.

Table 55. Reef fish population estimates for MHI CREMUS in 0-30 m hardbottom habitat only. *N* is number of sites surveyed per island.

ISLAND	Total Area of Reef (Ha)	*N*	Estimated population biomass (metric tons) in survey domain of < 30 m hardbottom					
			Acanthuridae	Carangidae	Carcharhinids	Holocentridae	Kyphosidae	Labridae
Kauai	18,127.1	82	859.6	242.3	-	94.0	111.0	247.7
Niihau	9,265.8	90	1,341.0	370.6	119.6	154.5	234.2	326.9
Oahu	25,118.8	171	804.5	67.1	-	3.8	27.3	170.0
Molokai	12,730.3	147	925.7	444.2	8.5	32.4	319.7	191.4
Maui	11,122.2	140	851.3	47.8	-	21.6	118.9	225.3
Lanai	3,003.7	88	245.3	22.0	-	12.0	3.3	45.1
Hawaii	16,839.8	198	1,563.1	123.6	-	132.0	139.0	247.7
TOTAL	**96,207.6**	**916**	**6,590.5**	**1,317.6**	**128.1**	**450.4**	**953.3**	**1,454.1**
ISLAND	**Total Area of Reef (Ha)**	***N***	**Lethrinidae**	**Lutjanidae**	**Mullidae**	**Scaridae**	**Serranidae**	
Kauai	18,127.1	82	25.9	489.0	121.3	385.2	124.6	
Niihau	9,265.8	90	79.6	1,215.9	193.8	492.0	305.9	
Oahu	25,118.8	171	9.9	36.9	86.5	151.3	29.0	
Molokai	12,730.3	147	51.3	254.3	157.1	418.1	153.5	
Maui	11,122.2	140	17.7	84.0	200.5	280.0	112.6	
Lanai	3,003.7	88	6.4	76.7	25.2	103.0	56.3	
Hawaii	16,839.8	198	93.2	279.9	175.5	522.2	305.0	
TOTAL	**96,207.6**	**916**	**284.0**	**2,436.8**	**959.8**	**2,351.9**	**1,087.0**	

2.1.5 Northwestern Hawaiian Islands Reef Fish Biomass

Description: 'Reef fish biomass' is mean biomass of reef fishes per unit area derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem and partners, as part of the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1).

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) 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.

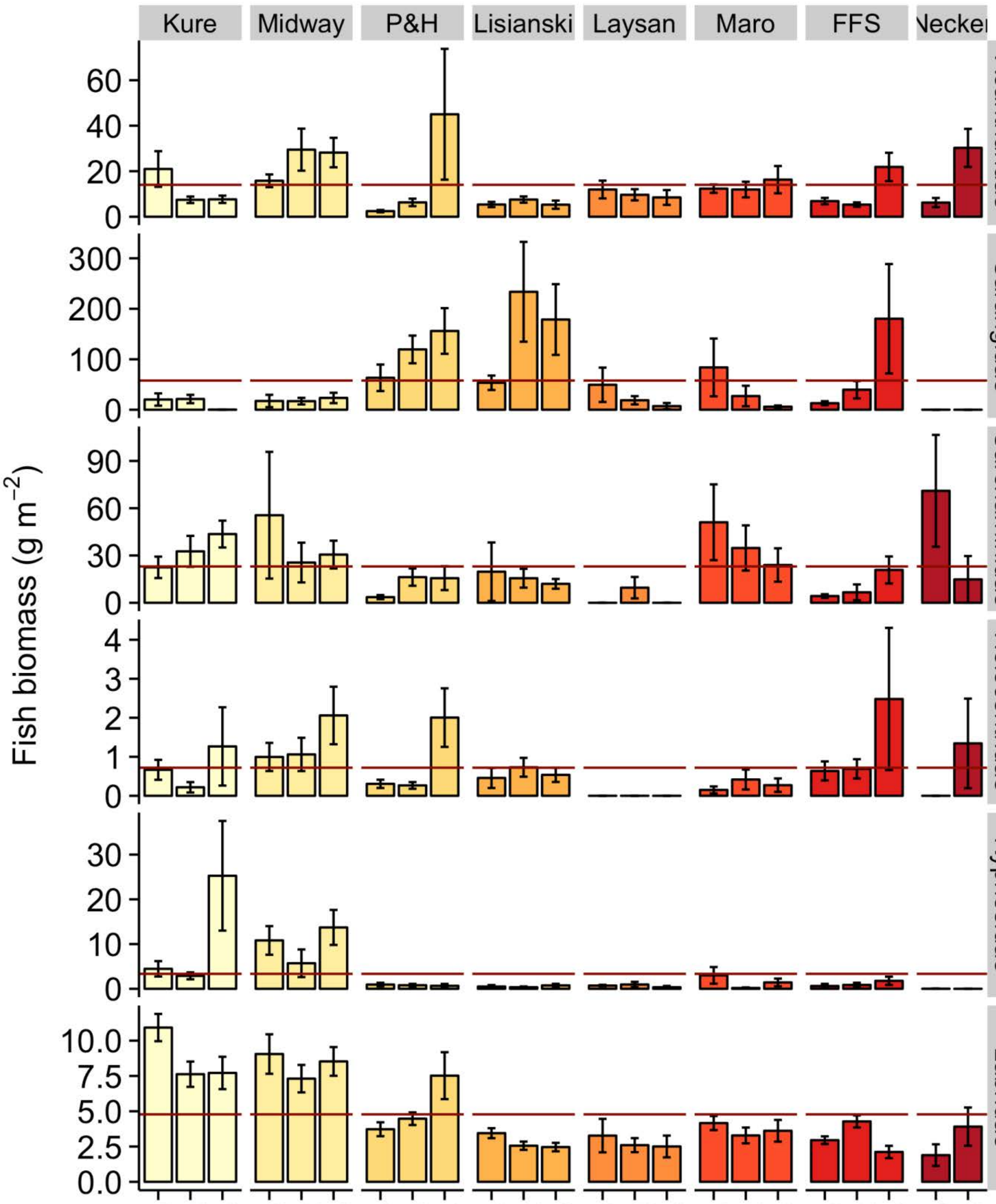
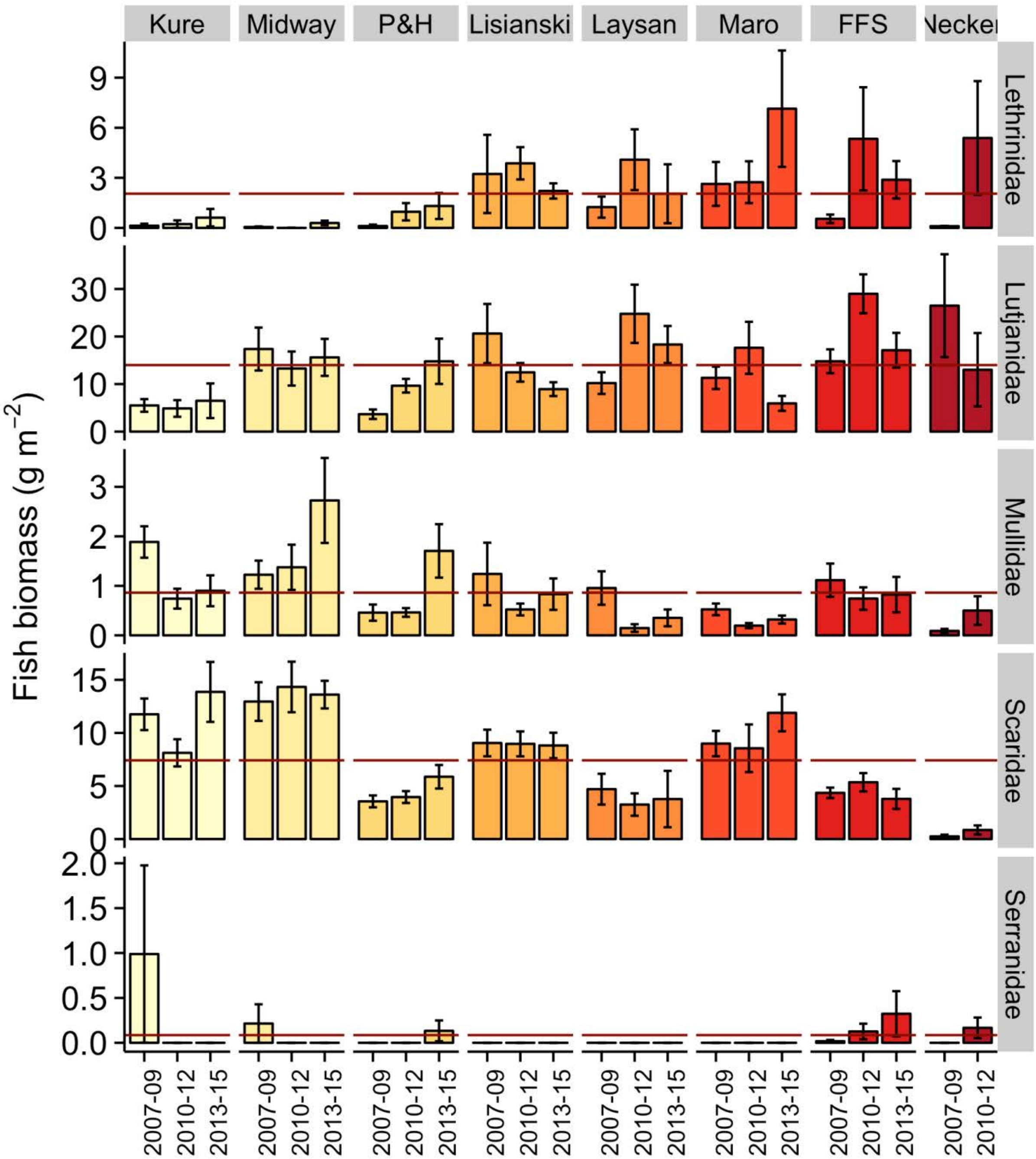


Figure 9. Mean fish biomass (g/m^2 ± standard error) of NWHI CREMUS from the years 2009-2015. The NWHI mean estimates are represented by the red line. Data from Nihoa and Gardner Pinnacles are removed, as data were limited. Figure continued on next page.


Kure
Midway
P&H
Lisianski
Laysan
Maro
FFS
Necker
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
Fish biomass (g m^{-2})
2007-09
2010-12
2013-15

2.1.6 Archipelagic Mean Fish Size

Description: 'Mean fish size' is mean size of reef fishes > 10 cm TL (i.e. excluding small fishes) derived from visual survey data (details of survey program below) between 2009 and 2015.

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate biomass estimates comes from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem. Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1).

Rationale: Reef fish biomass (i.e. the weight of fish per unit area) 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.

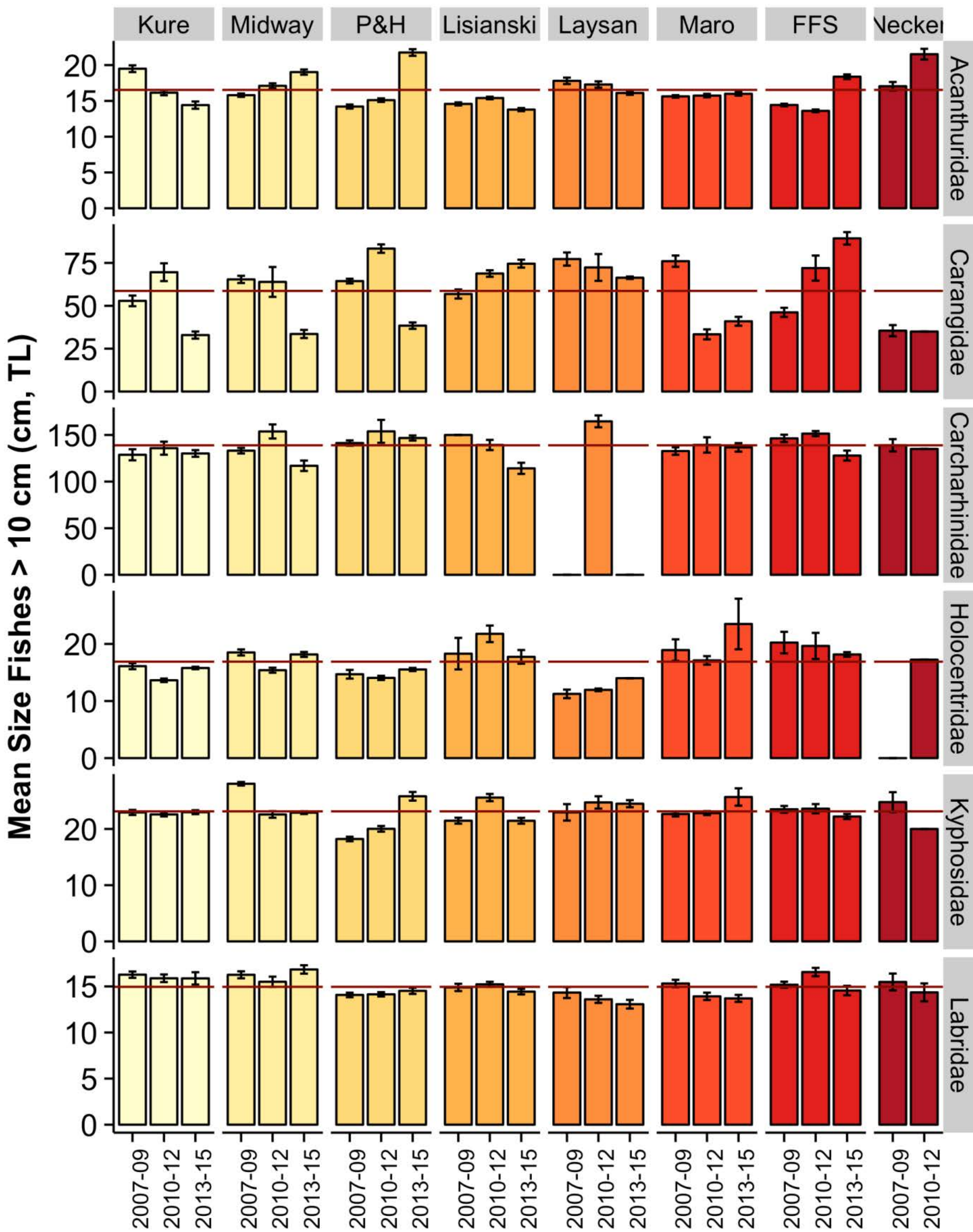
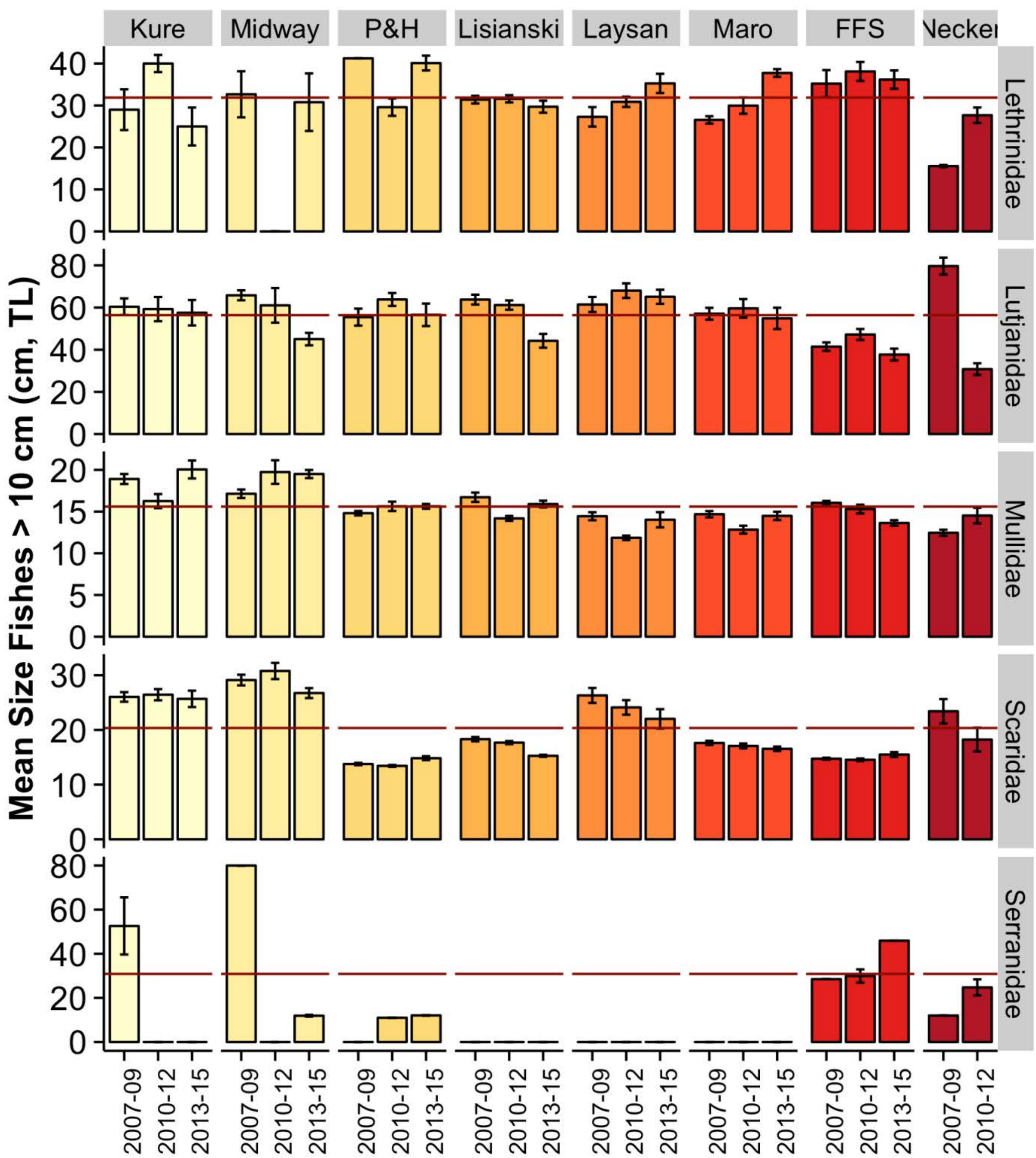


Figure 10. Mean fish size (cm, TL ± standard error) of NWHI CREMUS from the years 2009-2015. The NWHI mean estimates are plotted for reference (red line). Nihoa and

Gardner Pinnacles are removed, as data are very limited. Figure continued from previous page.



2.1.7 Reef Fish Population Estimates

Description: 'Reef fish population estimates' are calculated by multiplying mean biomass per unit area by estimated hardbottom area in a consistent habitat across all islands (specifically, the area of hardbottom forereef habitat in < 30 meters of water).

Category:
- ✓ Fishery independent
- ☐ Fishery dependent
- ☐ Biological

Timeframe: Triennial

Jurisdiction:
- ☐ Regional
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ☐ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Scale:
- ☐ Regional
- ☐ Archipelagic
- ✓ Island
- ☐ Site

Data Source: Data used to generate mean size estimates come from visual surveys conducted by NOAA PIFSC Coral Reef Ecosystem. Survey methods and sampling design, and methods to generate reef fish biomass are described above (Section 2.1.1). Those estimates are converted to population estimates by multiplying biomass (g/m^2) per island by the estimated area of hardbottom habitat <30 meters deep at the island, which is the survey domain for the monitoring program that biomass data comes from. Measures of estimated habitat area per island are derived from GIS bathymetry and NOAA Coral Reef Ecosystems Program habitat maps. Many reef fish taxa are present in other habitats than is surveyed by the program, and some taxa likely have the majority of their populations in deeper water. Additionally, fish counts have the potential to be biased by the nature of fish response to divers. Curious fishes, particularly in locations where divers are not perceived as a threat, will tend to be overestimated by visual survey, while skittish fishes will tend to be undercounted. It is also likely that numbers of jacks and sharks in some locations, such as the NWHI are overestimated by visual survey. Nevertheless, the data shown here are consistently gathered across space and time.

Rationale: These data have utility in understanding the size of populations from which fishery harvests are extracted.

Table 56. Reef fish population estimates for NWHI CREMUS in 0-30 m hardbottom habitat only. *N* is number of sites surveyed per island.

ISLAND	Total Area of Reef (Ha)	*N*	Estimated population biomass (metric tons) in survey domain of < 30 m hard bottom					
			Acanthuridae	Carangidae	Carcharhinids	Holocentridae	Kyphosidae	Labridae
Kure	3,699.4	53	279.0	399.3	1,410.2	27.4	521.0	283.6
Midway	4,995.6	78	1,440.5	1,008.2	1,401.5	77.9	485.2	395.6
Pearl & Hermes	17,812.1	113	4,570.0	24,530.7	2,839.1	202.2	130.7	1,067.8
Lisianski	30,954.9	105	1,985.5	63,822.4	4,268.3	196.1	171.6	776.7
Laysan	3,399.6	31	307.8	441.5	162.9	-	22.0	86.7
Maro	34,192.6	42	4,827.9	5,676.8	10,040.6	117.7	274.1	1,179.6
Gardner	31,733.2	12	1,423.4	4,315.8	15,991.0	-	426.3	340.7
French Frigate	27,797.4	85	3,781.5	30,580.0	3,814.6	440.9	367.8	888.5
Necker	636.6	8	192.6	0.1	94.4	8.6	0.0	24.9
Nihoa	409.9	8	59.3	110.9	43.0	3.0	31.1	16.1
TOTAL	**155,631**	**535**	**21,137.0**	**146,910.5**	**35,152.7**	**1,262.1**	**2,597.5**	**5,499.4**
ISLAND	**Total Area of Reef (Ha)**	***N***	**Lethrinidae**	**Lutjanidae**	**Mullidae**	**Scaridae**	**Serranidae**	
Kure	3,699.4	53	15.5	210.2	30.4	406.7	-	
Midway	4,995.6	78	7.3	721.3	102.4	697.8	-	
Pearl & Hermes	17,812.1	113	203.1	2,176.3	193.1	875.3	11.9	
Lisianski	30,954.9	105	941.3	3,311.5	209.6	2,752.9	-	
Laysan	3,399.6	31	104.2	732.6	8.5	119.3	-	
Maro	34,192.6	42	1,689.0	4,028.1	88.3	3,495.6	-	
Gardner	31,733.2	12	245.6	2,839.8	61.5	64.4	1.3	
French Frigate	27,797.4	85	1,142.2	6,407.8	217.5	1,269.8	62.5	
Necker	636.6	8	34.3	82.8	3.2	5.5	1.1	
Nihoa	409.9	8	7.2	27.9	3.3	19.4	8.0	
TOTAL	**155,631**	**535**	**4,815.7**	**20,907.9**	**1,028.0**	**11,024.8**	**94.6**	

2.2 LIFE HISTORY AND LENGTH-DERIVED PARAMETERS

2.2.1 MHI Coral Reef Ecosystem – Reef Fish Life History

2.2.1.1 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, particularly for long-lived (≥30 years) fish, is based on 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. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. 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 then subsequently 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 3- or 4-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 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function 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 ($A\Delta_{50}$).

Category:
- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ✓ Archipelagic
- ☐ Island
- ☐ Site

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. Refer to the "Reference" column in Table 57 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.

L_{∞} **(asymptotic length)** – One of three coefficients of the von Bertalanffy growth function (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 mean maximum length and not the observed maximum length.

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 (0+ to 1+ ages) are not available for age determination.

***M* (natural mortality)** – this is a measure of mortality rate for a fish stock not under the influence of fishing pressure 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 two 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.

$A\Delta_{50}$ (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.

L_{50} (length at which 50% of a fish species are capable of spawning) – Length (usually in terms of fork 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 & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork 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 & growth.

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 fish resources in Hawaii is 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 57. Available age, growth, and reproductive maturity information for coral reef species targeted for life history sampling (otoliths and gonads) in the Hawaiian Archipelago.

Species	Age, growth, and reproductive maturity parameters								Reference
	T_{max}	L_∞	k	t_0	A_{50}	$A\Delta_{50}$	L_{50}	$L\Delta_{50}$	
Calotomus carolinus	4[d]				1.3[d]	3.2 [d]	24[d]	37[d]	DeMartini *et al.* (2017), DeMartini and Howard (2016)
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)
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)
Naso unicornis	54[d]	47.8[d]	0.44[d]	-0.12[d]					Andrews *et al.* (2016)

Notes:
[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).

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 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.

2.2.2 MHI Bottomfish Ecosystem – Bottomfish Life History

2.2.2.1 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, particularly for long-lived (≥30 years) fish, is based on 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. The relation between age and fish length is evaluated by fitting this data to a von Bertalanffy growth function based on statistical analyses. The resulting von Bertalanffy growth function predicts the pattern of growth over time for that particular species. 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 then subsequently 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 3- or 4-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 50% sex reversal ($A\Delta_{50}$) is typically derived by referencing the von Bertalanffy growth function 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 ($A\Delta_{50}$).

Category:

- ☐ Fishery independent
- ☐ Fishery dependent
- ✓ Biological

Timeframe: N/A

Jurisdiction:
- ☐ American Samoa
- ☐ Guam
- ☐ Commonwealth of Northern Mariana Islands
- ✓ Main Hawaiian Islands
- ✓ Northwest Hawaiian Islands
- ☐ Pacific Remote Island Areas

Spatial Scale:
- ☐ Regional
- ✓ Archipelagic
- ☐ Island
- ☐ Site

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. Refer to the "Reference" column in Table 58 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.

L_∞ (asymptotic length) – One of three coefficients of the von Bertalanffy growth function (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 mean maximum length and not the observed maximum length.

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 (0+ to 1+ ages) are not available for age determination.

***M* (natural mortality)** – this is a measure of mortality rate for a fish stock not under the influence of fishing pressure 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 two 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.

$A\Delta_{50}$ (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.

L_{50} (length at which 50% of a fish species are capable of spawning) – Length (usually in terms of fork 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 & growth.

$L\Delta_{50}$ (length of sex switching) – Length (usually in terms of fork 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 & growth.

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 fish resources in Hawaii is 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 58. Available age, growth, and reproductive maturity information for bottomfish species targeted for life history sampling (otoliths and gonads) 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	31[b]	77.1[b]	0.37[b]	-0.51[b]	X[a]		NA	42.5-47.5[d]	NA	Everson *et al*. (1989); O'Malley *et al*. (in prep.)
Etelis carbunculus	X[a]	X[a]	X[a]	X[a]	X[a]		NA	23.4[d]	NA	Nichols *et al*. (in prep); DeMartini *et al*. (2017)
Etelis coruscans	X[a]	X[a]	X[a]	X[a]		X[a]	NA	X[a]	NA	Andrews *et al*. (in prep); Reed *et al*. (in prep.)
Hyporthodus quernus	X[a]	X[a]	X[a]	X[a]				58.0[d]	89.5[d]	Andrews *et al*. (in prep); DeMartini *et al*. (2017)
Pristipomoides filamentosus	42[d]	67.5[d]	0.24[d]	-0.29[d]			NA	40.7[d]	NA	Andrews *et al*. (2012)
Pristipomoides sieboldii							NA	23.8[d]	NA	DeMartini (2017)
Pristpomoides zonatus							NA		NA	

Notes:
[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).

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 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.

2.2.3 References

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2.3 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 (Western Pacific Regional Fishery Management Council, 2016). 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 11), which is reflected in local culture, customs, and traditions.

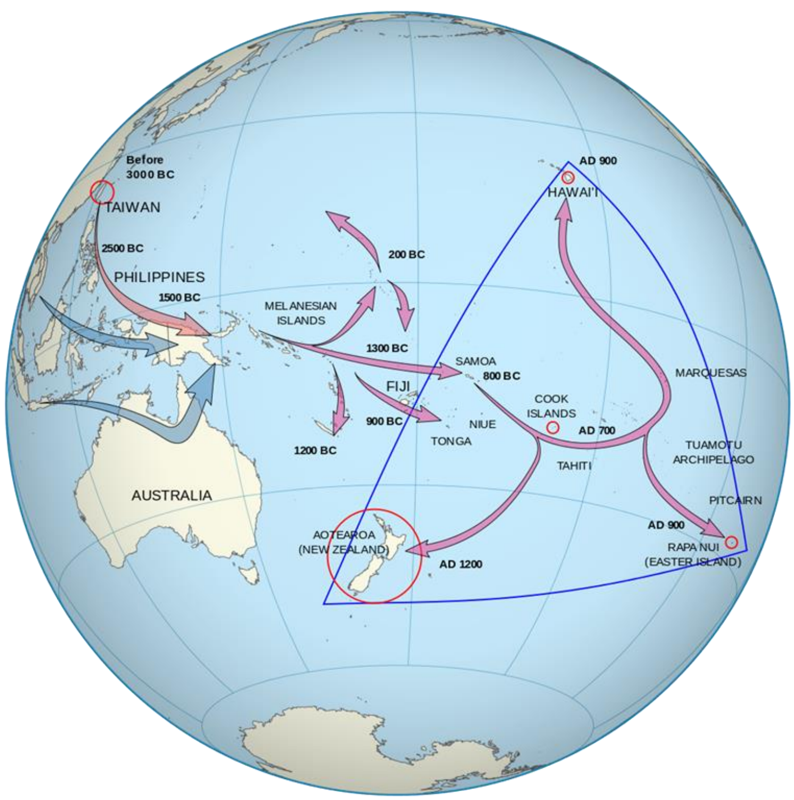

Figure 11. Settlement of the Pacific Islands, courtesy Wikimedia Commons https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg.

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 economics are 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.

2.3.1 Response to Previous Council Recommendations

At its 165th meeting held in Honolulu, Hawaii, the Council approved modifications to the FEP objectives, one of which is to identify the various social and economic groups within the region's fishing communities and their interconnections in support of fishing communities themselves. This chapter meets this objective.

At its 166th meeting held in Tumon, Guam, the Council directed staff to develop a brief report identifying data sources, quality, and coverage for each required socioeconomic parameter in the annual SAFE reports as resources permit. This report should also identify the quality and coverage of this data, as well as any gaps. This data synthesis was conducted and used to guide the development of this chapter with further input and guidance from the Council Social Science Planning Committee and Archipelagic Plan Team.

The Council also directed the Plan Team to consider for future Annual/SAFE reports:

- To include the human perspective, the importance of the community, and the extended cultural and social values of fishing in the dashboard summary format. This chapter is the first effort at including the importance of community and extended cultural and social values into a SAFE report in this region.
- To include enhanced information on social, economic, and cultural impacts of a changing climate and increased pressure on the ocean and its resources. PIFSC developed a Regional Action Plan and Climate Science Strategy as a first step in providing this information (Polovina *et al*., 2016).

2.3.2 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 (Western Pacific Regional Fishery Management Council, 2009). Over the past decade, a number of 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 fish ponds, 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 2010 Census, the State of Hawaii's population was almost 1.4 million during the last census. Ethnically, it has the highest percentage of Asian Americans (38.6%) and multiracial Americans (23.6%) while having the lowest percentage of White Americans (24.7%) of all states. Approximately 21% of the population identifies as Native Hawaiian or part Native Hawaiian. Tourism from many 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 Hawaiʻi, with the level of commercial fishing-related employment well above the national average (Richmond *et al*., 2015). The Fisheries Economics of the United States 2014 report found that the seafood industry (including the commercial harvest sector, seafood processors and dealers, seafood wholesalers and distributors, importers, and seafood retailers) generated $743 million in sales impacts and approximately 10,000 full and part-time jobs that year (NMFS, 2016). Recreational anglers took 1.4 million fishing trips, and 1,061 full- and part-time jobs were generated by recreational fishing activities in the state. Similarly, the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Department of the Interior *et al*., 2011) estimated that 157,000 people over 16 years old participated in saltwater angling in Hawai'i. 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 in the 2006 and 2001 national surveys.

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*., 2010; 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 (National Coral Reef Monitoring Program, 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 (National Coral Reef Monitoring Program, 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 fishers 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 ʻahi poke (bite-sized cubes of seasoned raw tuna) and ahi sashimi (sliced raw tuna). ʻAhi 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 Hawaiʻi'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).

2.3.3 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 number of participants involved in small boat fishing increased between 2003 and 2013 from 1,587 small boat-based commercial marine license holders to 1,843 (excluding charter, aquarium, and precious coral fisheries, Chan and Pan, 2017). Together, these small boat fishermen produced 6.2 million pounds of fish in 2013, with a commercial value of around $16 million.

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, the majority of 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 59.

Table 59. 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 59). 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 motor boat (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.

The National Marine Fisheries Service (NMFS) and the Hawai‘i Division of Aquatic Resources (DAR) have been collecting information on recreational fishing in Hawai‘i, administered through the Hawai‘i 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.

2.3.4 Costs of Fishing

Past research has documented the costs of fishing in Hawaii (Hamilton and Huffman, 1998; 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). 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 60 provides estimates for the cost of an average boat-based bottomfish or reef fish-targeted trip during 2014. Estimates for annual fishing expenditures (fixed costs) and levels of investment in the fishery are also provided in the literature.

Table 60. Bottomfish and reef fish trip costs in 2014 for small boats in Hawaii.

Cost	Bottomfish Handline		Reef Spearfish	
	$ per trip	% of total trip cost	$ per trip	% of total trip cost
Fuel	134.24	53%	86.26	54%
Non-fuel	118.34	47%	72.68	46%
Total cost	252.58	100%	158.94	100%

Source: PIFSC Socioeconomics Program: Hawaii small boat cost-earnings data: 2014. Pacific Islands Fisheries Science Center, https://inport.nmfs.noaa.gov/inport/item/29820.

2.3.5 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 bottomfishing 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. Bottomfishing 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 bottomfishing outweigh economic prospects.

2.3.5.1 Commercial Participation, Landings, Revenues, Prices

This section will describe trends in commercial participation, landings, revenues, and prices, as data allows, for the Hawaii bottomfish fishery. Supporting figures and tables will be added in future reports.

2.3.5.2 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, opakapaka, kalekale, gindai, lehi, and hapuupuu. 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.

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). 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 the fishery are shown in Figure 12 while trends in revenue per trip and the share of Deep 7 as a percentage of total fishery revenues are shown in Figure 13. In these figures "fishery" revenues refers only to Deep 7 bottomfish species catch and revenues and excludes other species (such as non-Deep 7 bottomfish, pelagic, and other species) caught on Deep 7 fishing trips. Supporting data are provided in Table 61, where the last column reflects the share of Deep 7 bottomfish in total fishing revenues (all species combined) on Deep 7 fishing trips for fishermen active in the MHI Deep 7 bottomfish fishery.

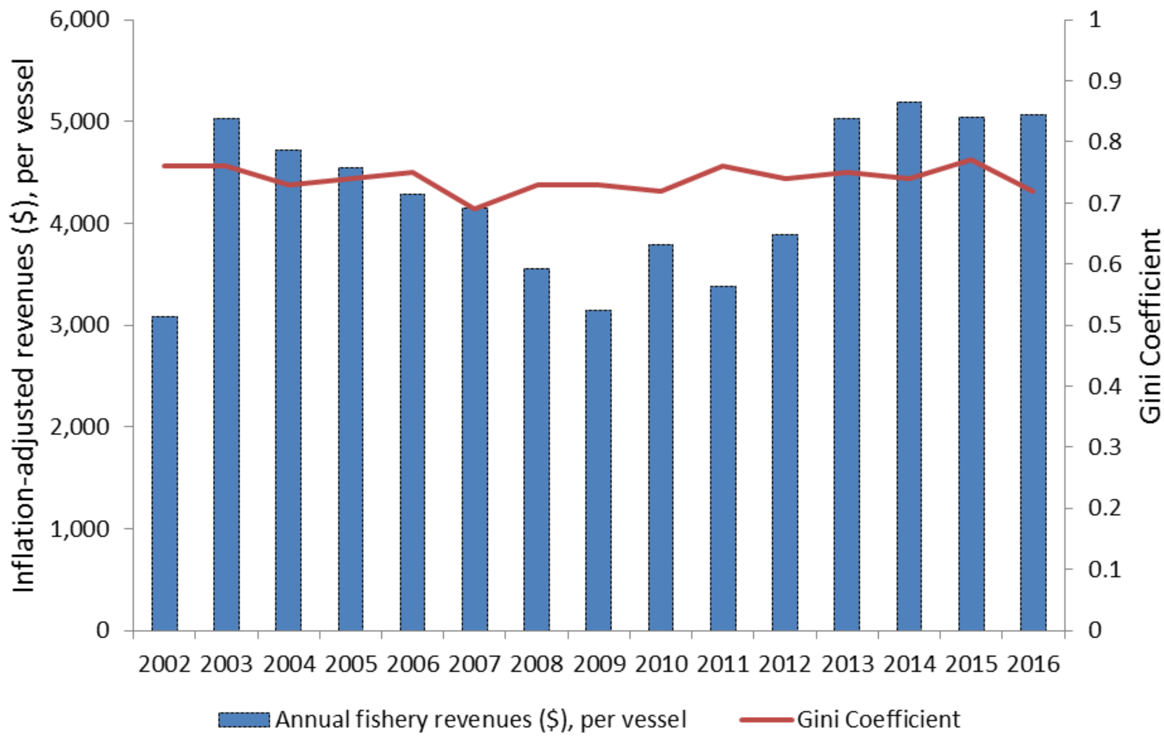

Figure 12. Trends in fishery revenue per vessel and Gini coefficient for the MHI Deep 7 Bottomfish fishery

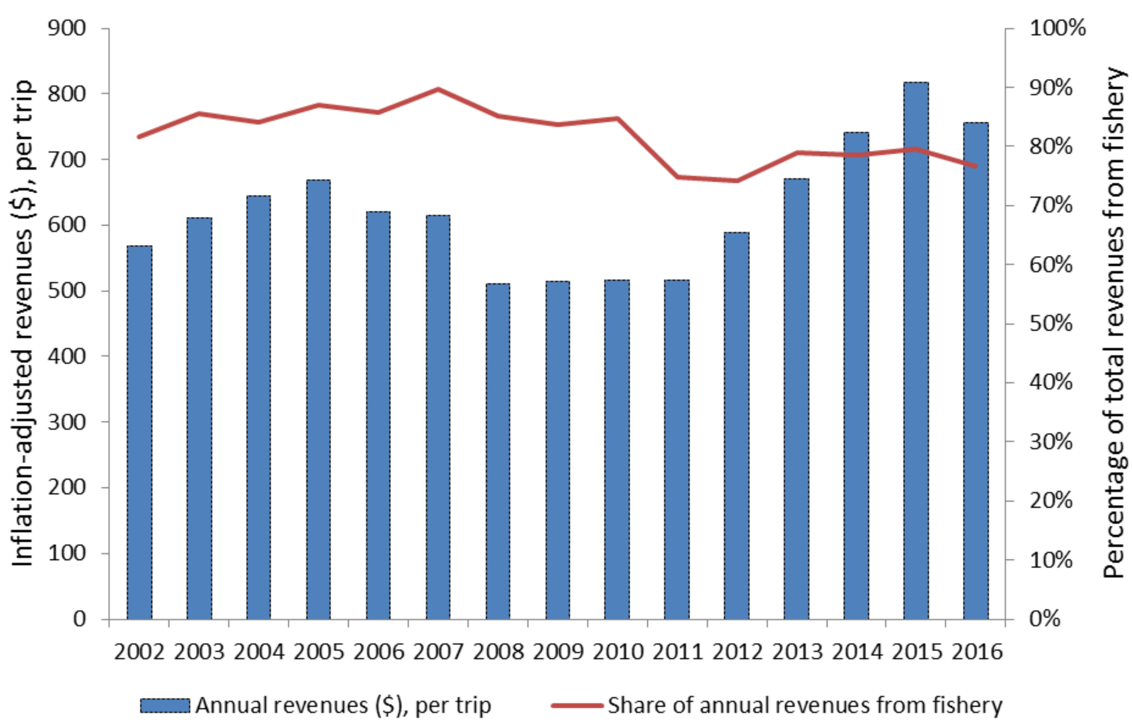

Figure 13. Trends in fishery revenue per trip and Deep 7 as a percentage of total revenues for the MHI Deep 7 Bottomfish fishery

Table 61. MHI Deep 7 bottomfish fishery economic performance measures

Year	Annual fishery revenues ($)[1], per vessel	Annual fishery revenues ($), per vessel (Nominal)	Annual fishery revenues ($)[1], per trip	Annual fishery revenues ($), per trip (Nominal)	Gini coefficient	% Annual revenues ($) from fishery
2002	3,079	2,093	569	387	0.76	81.7
2003	5,026	3,495	611	425	0.76	85.6
2004	4,722	3,392	644	463	0.73	84.1
2005	4,550	3,393	668	498	0.74	86.9
2006	4,282	3,380	620	489	0.75	85.9
2007	4,144	3,428	615	509	0.69	89.7
2008	3,553	3,066	511	441	0.73	85.1
2009	3,149	2,731	515	447	0.73	83.8
2010	3,784	3,352	517	458	0.72	84.7
2011	3,378	3,102	516	474	0.76	74.8
2012	3,888	3,658	589	554	0.74	74.1
2013	5,033	4,816	671	642	0.75	78.9
2014	5,184	5,033	742	720	0.74	78.5
2015	5,038	4,939	817	801	0.77	79.5
2016	5,061	5,061	756	756	0.72	76.7

[1] Inflation-adjusted revenue (in 2016 dollars) use 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, https://inport.nmfs.noaa.gov/inport/item/46097

2.3.6 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[1].

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 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.

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

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.

2.3.6.1 Commercial Participation, Landings, Revenues, Prices

This section will describe trends in commercial participation, landings, revenues, and prices, as data allows, for the Hawaii coral reef fish fishery. Supporting figures and tables will be added in future reports.

2.3.7 Crustaceans

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

2.3.8 Precious Corals

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

2.3.9 Ongoing Research and Information Collection

Social indicators are being compiled, in accordance with a national project to describe and evaluate community well-being in terms of social, economic, and psychological welfare (https://www.st.nmfs.noaa.gov/humandimensions/social-indicators/index). Through 2017, a web-based tool has been in development to compile relevant socioeconomic data into a "Community Snapshot" by Census County Division. In addition, an external review of the Economics and Human Dimensions Program was undertaken (PIFSC, 2017). Recommendations will help focus and prioritize a strategic research agenda.

2.3.10 Relevant PIFSC Economics and Human Dimensions Publications: 2017

Chan, H.L. and Pan, M., 2017. Economic and social characteristics of the Hawaii small boat fishery 2014. U.S. Dept. of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-63, 97 p. https://doi.org/10.7289/V5/TM-PIFSC-63.

Pacific Islands Fisheries Science Center (PIFSC), 2017. Background and PIFSC Response: Panel Reports of the Economics and Human Dimensions Program Review. 18 p. https://go.usa.gov/xnDyP.

Pacific Islands Fisheries Science Center (PIFSC) Socioeconomics Program, 2017. Potential Economic Impacts of the Papahānaumokuākea Marine National Monument Expansion. Pacific Islands Fisheries Science Center, PIFSC Internal Report, IR-17-06, 14p.

Pacific Islands Fisheries Science Center (PIFSC), 2017. Hawaii Community Snapshot Tool. https://www.pifsc.noaa.gov/socioeconomics/hawaii-community-snapshots.php.

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Western Pacific Regional Fishery Management Council, 2016. Annual Stock Assessment and Fishery Evaluation Report for the Hawaii Archipelago Fishery Ecosystem Plan. Honolulu, HI. 88 p. + Appendices.

2.4 PROTECTED SPECIES

This section of the report summarizes information on protected species interactions in fisheries managed under the Hawai`i 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 Hawai`i waters and a list of critical habitat designations in the Pacific Ocean are included in Appendix B.

2.4.1 Indicators for Monitoring Protected Species Interactions

This report monitors the status of protected species interactions in the Hawai`i 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.

2.4.1.1 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.

2.4.1.2 ESA Consultations

Hawai`i 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 Hawai`i Archipelago (Table 62).

In January 2018, oceanic whitetip sharks and giant manta rays were listed under the ESA (83 FR 4153 and 83 FR 2916, respectively). NMFS will reinitiate consultation for those two species for the applicable fisheries if NMFS determines that effects are likely. There is no record of giant manta ray incidental catches in Hawaiian non-longline fisheries, and NMFS is reviewing catch data on oceanic white tip shark incidental catch in these fisheries.

Table 62. Summary of ESA consultations for Hawai`i FEP Fisheries.

Fishery	Consultation Date	Consultation Type[a]	Outcome[b]	Species
Bottomfish	3/18/2008	BiOp	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green 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)
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)
Coral reef ecosystem (Kona Kanpachi 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)
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)

Fishery	Consultation Date	Consultation Type[a]	Outcome[b]	Species
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)
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.

2.4.1.2.1 Bottomfish Fishery

In a March 18, 2008 Biological Opinion (BiOp) covering MHI bottomfish fishery, NMFS determined that the MHI bottomfish fishery is not likely to jeopardize the green 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 MHI insular false killer whale distinct population segment 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 bottomfishing activities, the low likelihood of collisions, and the lack of observed or reported fishery interactions were among other reasons.

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

2.4.1.2.2 Crustacean Fishery

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawai`i 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, Northern right whale, 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 Hawai`i crustacean fishery is not likely to adversely affect monk seal critical habitat.

2.4.1.2.3 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 listed species under USFWS's exclusive jurisdiction (i.e., seabirds) and listed species shared with NMFS (i.e., sea turtles).

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawai`i 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 whale, 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 Hawai`i coral reef ecosystem fishery is not likely to adversely affect monk seal critical habitat.

2.4.1.2.4 Precious Coral Fishery

In an informal consultation completed on December 5, 2013, NMFS concluded that the Hawai`i 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, Northern right whale, 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 Hawai`i precious coral fishery is not likely to adversely affect monk seal critical habitat.

2.4.1.3 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 2018 LOF (83 FR 5349, February 7, 2018), 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).

2.4.2 Status of Protected Species Interactions in the Hawai`i FEP Fisheries

2.4.2.1 Bottomfish Fishery

Fisheries operating under the Hawai`i 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 bottomfishing 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 protected species from this fishery have changed in recent years.

2.4.2.2 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 Hawai`i FEP. However based on current ESA consultations, these fisheries are not expected to interact with any ESA-listed species in federal waters around the Hawai`i Archipelago. NMFS has also concluded that the Hawai`i crustacean, coral reef, and precious coral commercial fisheries will not affect marine mammals in any manner not considered or authorized under the Marine Mammal Protection Act.

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, 2016).

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.

2.4.3 Identification of Emerging Issues

Several ESA-listed species are being evaluated for critical habitat designation (Table 63). If critical habitats are designated, they will be included in this SAFE report and impacts from FEP-managed fisheries will be evaluated under applicable mandates.

Table 63. Candidate ESA species, and ESA-listed species being evaluated for critical habitat designation.

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)	Not determinable because of insufficient data (83 FR 4153, 1/30/18)	TBA

Species		Listing process			Post-listing activity	
Common name	Scientific name	90-day finding	12-month finding / Proposed rule	Final rule	Critical Habitat	Recovery Plan
Pacific bluefin tuna	*Thunnus orientalis*	Positive (81 FR 70074, 10/11/2016)	Not warranted (82 FR 37060, 8/8/17)	N/A	N/A	N/A
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)	Not determinable because of insufficient data (83 FR 2916, 1/22/18)	TBA
Reef manta ray	*Manta alfredi*	Positive (81 FR 8874, 2/23/2016)	Not warranted (82 FRN 3694, 1/12/2017)	N/A	N/A	N/A
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)	Critical habitat maps proposed (82 FR 51186, 11/3/17), comment period closed 1/2/18, final rule expected 7/1/2018	In development, public comment expected 2018
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[a]	TBA

[a] NMFS and USFWS have been tasked with higher priorities regarding sea turtle listings under the ESA, and do not anticipate proposing green turtle critical habitat designations in the immediate future.

2.4.4 Identification of Research, Data, and Assessment Needs

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

- Improve the precision of commercial and non-commercial fisheries data to improve understanding of potential protected species impacts.
- Define and evaluate innovative approaches to derive robust estimates of protected species interactions in insular fisheries.
- Update analysis of fishing-gear related strandings of Hawai`i green turtles.

2.4.5 References

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Nitta, E. 1999. Draft: Summary report: Bottomfish observer trips in the Northwestern Hawaiian Islands, October 1990 to December 1993. Honolulu, Hawaii, NMFS Pacific Islands Area Office, Pacific Islands Protected Species Program.

WPFRMC, 2009. Fishery Ecosystem Plan for the Hawaii Archipelago. WPFRMC, Honolulu, Hawaii, 286 p.

WPRFMC, 2017. Annual Stock Assessment and Fishery Evaluation Report: Hawaii Archipelago Fishery Ecosystem Plan 2016. WPFRMC, Honolulu, Hawaii, 533 p.

2.5 CLIMATE AND OCEANIC INDICATORS

2.5.1 Introduction

Beginning with the 2015 Annual Report, we have included a chapter on indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Western Pacific Regional Fishery Management Council has responsibility. There are a number of 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:

- 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; the development of a Climate Science Strategy by the National Marine Fisheries Service (NMFS) in 2015 and the ongoing development of Pacific Regional Climate Science program
- The Council's own engagement with the National Oceanic and Atmospheric Administration (NOAA) as well as jurisdictional fishery management agencies in American Samoa, the Commonwealth of the Northern Mariana Islands, Guam and Hawaii as well as fishing industry representatives and local communities in those jurisdictions; and
- Deliberations of the Council's Marine Planning and Climate Change Committee.

Starting with the 2015 Report, the Council and its partners have provided continuing descriptions of changes in a series of climate and oceanic indicators that will grow and evolve over time as they become available and their relevance to Western Pacific fishery resources becomes clear.

2.5.2 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:

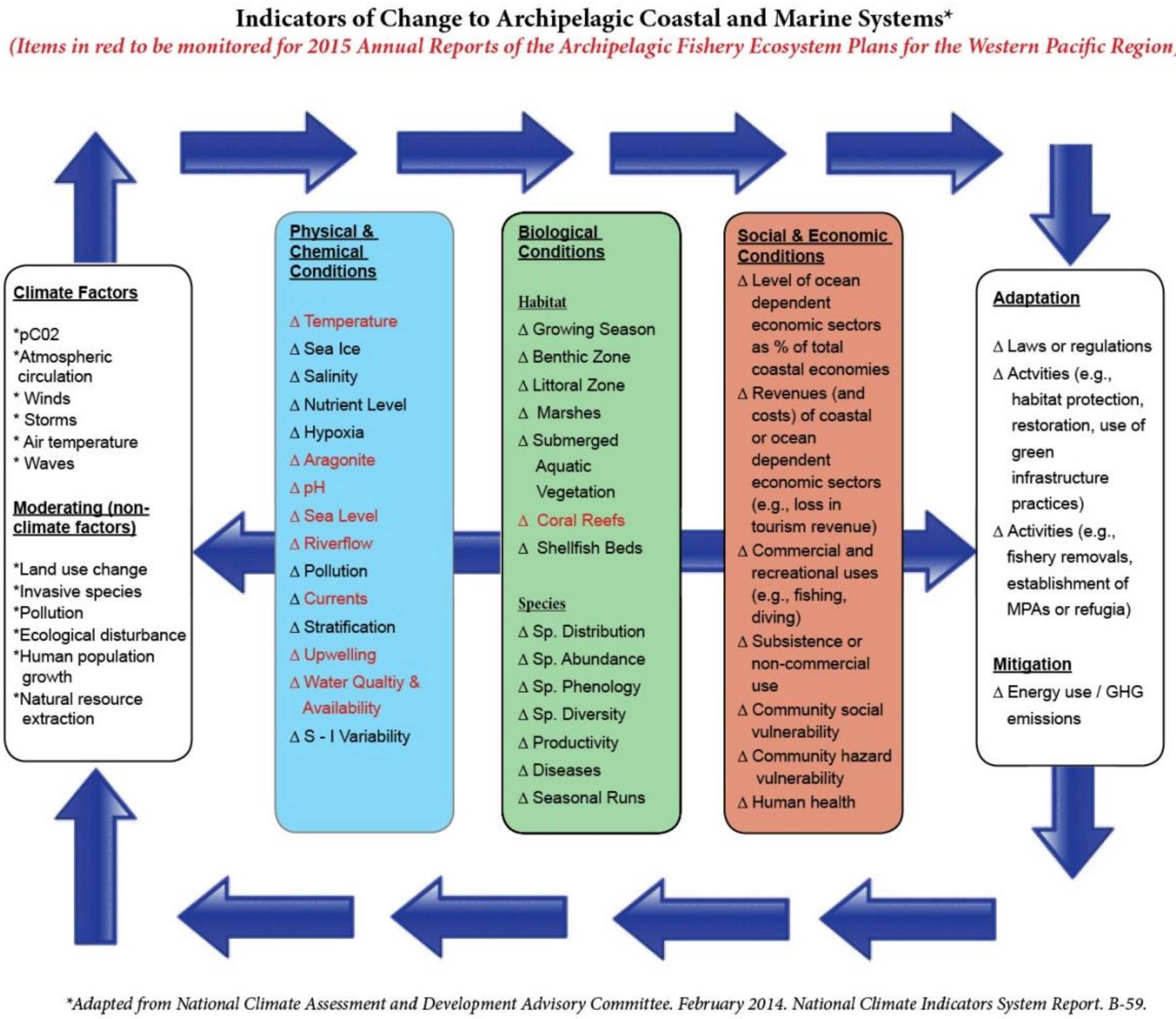


Figure 14. Simplified representation of the climate and non-climate stressors in the coastal and marine ecosystems.

As described in the 2014 NCADAC report, the conceptual model represents 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 2015 Annual Report; the specific indicators used in the Report are listed in Section 2.4. Other indicators will be added over time as datasets become available and understanding of the nature 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 that will enable the Council and its partners to move from observations and correlations to understanding the specific nature of interactions and developing capabilities to predict future changes of importance in developing, evaluating, and adapting ecosystem-fishery plans in the Western Pacific Region.

2.5.3 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.

Beginning with the 2015 report on Western Pacific Pelagic resources, the Council has included the following climate and oceanic indicators:

Atmospheric Carbon Dioxide (at Mauna Loa Observatory) – Increasing atmospheric CO_2 is a primary measure of anthropogenic climate change.

Ocean pH (at Station ALOHA) – Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures.

Oceanic Niño Index (ONI) – Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region affecting migratory patterns of key commercial fish stocks which, in turn, affect the location, safety and costs of commercial fishing.

Pacific Decadal Oscillation (PDO) – Like ENSO, the PDO reflects changes between periods of persistently warm or persistently cool ocean temperatures, but over a period of 20 – 30 years versus 6 – 18 months for ENSO event. The climatic finger prints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Sea Surface Temperature – Monthly sea surface temperature and anomaly blended from three data sources covering 1985-2017: Pathfinder v 5.0, the Global Area Coverage, and the GOES-POES dataset from both the AVHRR instrument aboard the NOAA Polar Operational Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES). Sea surface temperature is one of the most directly observable measures we have for tracking increasing ocean temperature.

Sea Surface Temperature Anomaly – Sea surface temperature anomaly highlights long term trends. Filtering out seasonal cycle, and showing the current year relative to past years, sea surface temperature anomaly provides context on one of the most directly observable measures we have for tracking increasing ocean temperature.

Coral Thermal Stress Exposure – In tropical coastal habitats, one tangible impact of high temperature anomalies is the possibility of mass coral bleaching. To help gauge the history and impact of thermal stress on coastal corals, we present a satellite-derived metric called Degree Heating Weeks.

Chlorophyll-A – Monthly chlorophyll-*a* spanning 2002-2017 from the MODIS sensor aboard the NASA Aqua satellite. Chlorophyll-A is derived from ocean color, and is a proxy for the amount of phytoplankton in the seawater. Combined with temperature, it can give an index of primary production.

Chlorophyll-Anomaly – Deviation from seasonal and inter-annual chlorophyll-a (chl-A) patterns can provide a means of assessing the relative distinctiveness of 2017, as well as how chl-A varies over time.

Heavy Weather (Tropical Cyclones & Storm Force Winds) -- Measures of tropical cyclone occurrence, strength, and energy. Percentage occurrence of winds > 34 knots. Tropical cyclones and high winds may have the potential to significantly impact fishing operations.

Rainfall – Rainfall has been proposed as a potentially important correlate for the catch of some nearshore species, especially nearshore pelagics.

Sea Level (Sea Surface Height) and Anomaly – 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. Note that no water level gauges are available in PRIA so only regional information on this Indicator is included.

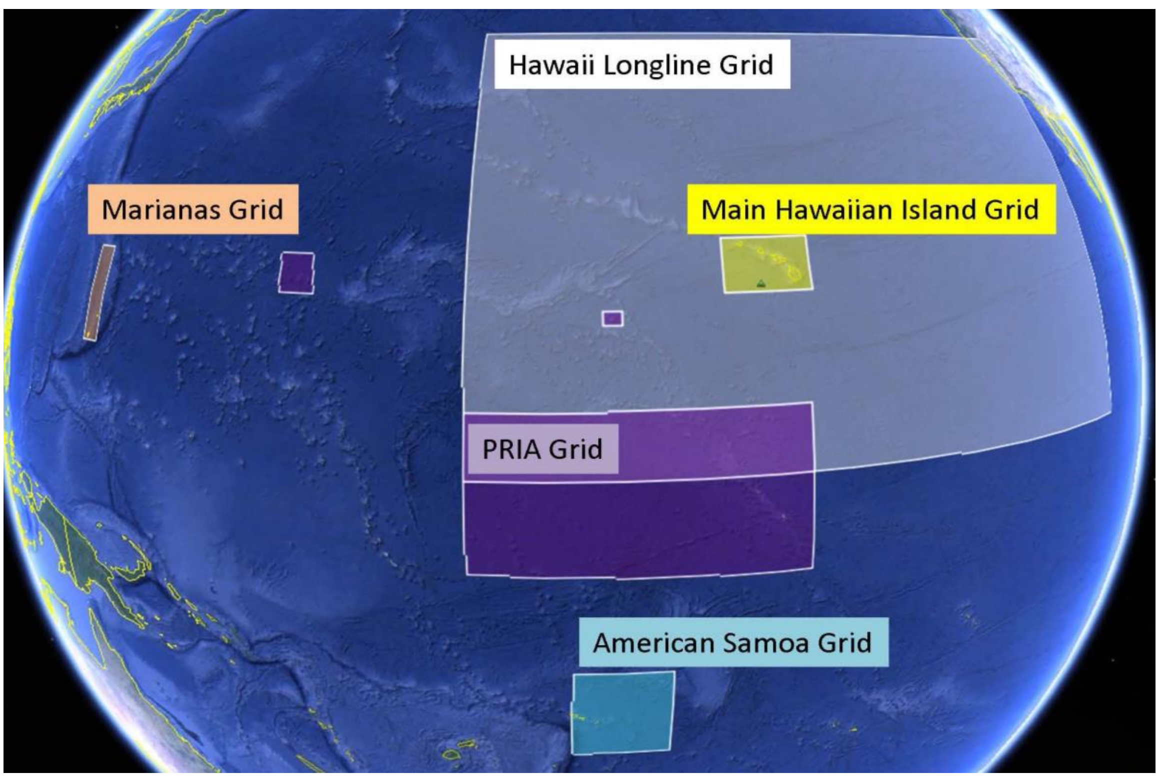


Figure 15. Regional spatial grids representing the scale of the climate change indicators being monitored.

Table 64. Climate and ocean indicator summaries for 2017.

Indicator	Definition and Rationale	Indicator Status
Atmospheric Concentration of Carbon Dioxide (CO_2)	Atmospheric concentration CO_2 at Mauna Loa Observatory. Increasing atmospheric CO_2 is a primary measure of anthropogenic climate change.	Trend: increasing exponentially 2017: time series mean 406.53 ppm
Oceanic pH	Ocean surface pH at Station ALOHA. Ocean pH provides a measure of ocean acidification. Increasing ocean acidification limits the ability of marine organisms to build shells and other hard structures.	Trend: pH is decreasing at a rate of 0.039 pH units per year, equivalent to 0.4% increase in acidity per year
Oceanic Niño Index (ONI)	Sea surface temperature anomaly from Niño 3.4 region (5°N - 5°S, 120° - 170°W). This index is used to determine the phase of the El Niño – Southern Oscillation (ENSO), which has implications across the region, affecting migratory patterns of key commercial fish stocks which in turn affect the location, safety, and costs of commercial fishing.	2017: ENSO Neutral
Pacific Decadal Oscillation (PDO)	PDO can be thought of as a long-lived, multi-decadal ENSO cycle that has well-documented fishery implications related to ocean temperature and productivity.	2017: positive (warm) from Jan – June, negative (cool) from Jul – Dec
Sea Surface Temperature* (SST)	Satellite remotely-sensed sea surface temperature. SST is projected to rise, and impacts phenomena ranging from winds to fish distribution.	SST in waters surrounding most of PRIA ranged between 27-30º C with 2017 showing anomalies dependent on latitude: along the equator, 2017 showed a negative anomaly, while at ~4 deg N, the 2017 anomaly moves positive.
Coral Thermal Bleaching Exposure (DHW)	Satellite remotely-sensed metric of time and temperature above thresholds relevant for coral bleaching. Metric used is Degree Heating Weeks (DHW).	The equatorial PRIA showed prolonged, substantial DHW stress in 2015-2016, in which DHW values exceeded the range in which mass mortality is expected (DHW>8). Wake Atoll showed more regular, but less prolonged heating events ('14, '15, '17).
Chlorophyll-A (Chl-A)	Satellite remotely-sensed chlorophyll-a. Chl-A is projected to drop over much of the central Pacific, and is directly linked ecosystem productivity.	The Chl-A around the PRIA ranges from 0.08 to 0.35 mg/m^3, with 2017 showing a near-zero and spatially variable anomaly.
Tropical Cyclones	Measures of tropical cyclone occurrence, strength, and energy. Tropical cyclones have the potential to significantly impact fishing operations.	Eastern Pacific, 2017: 31 storms, a level slightly lower than average.
		South Pacific, 2017: 6 storms, low – lowest since 2012.
		Central Pacific, 2017: 0 storms. Very low.
Rainfall/Precipitation	CMAP re-analysis of CPC Precipitation Data	2017 showed negative anomalies in rainfall.

Sea Level/Sea Surface Height	Monthly mean sea level time series, including extremes. Data from satellite altimetry & in situ tide gauges. 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.	Although varying over time the monthly mean sea level trend is increasing.

2.5.3.1 Atmospheric Concentration of Carbon Dioxide (CO_2) at Mauna Loa

Rationale: Atmospheric carbon dioxide 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. In 2017, the annual mean concentration of CO_2 was 406.53 ppm. In 1959, the first year of the time series, it was 315.97 ppm. The annual mean passed 350 ppm in 1988 and 400 ppm in 2015.

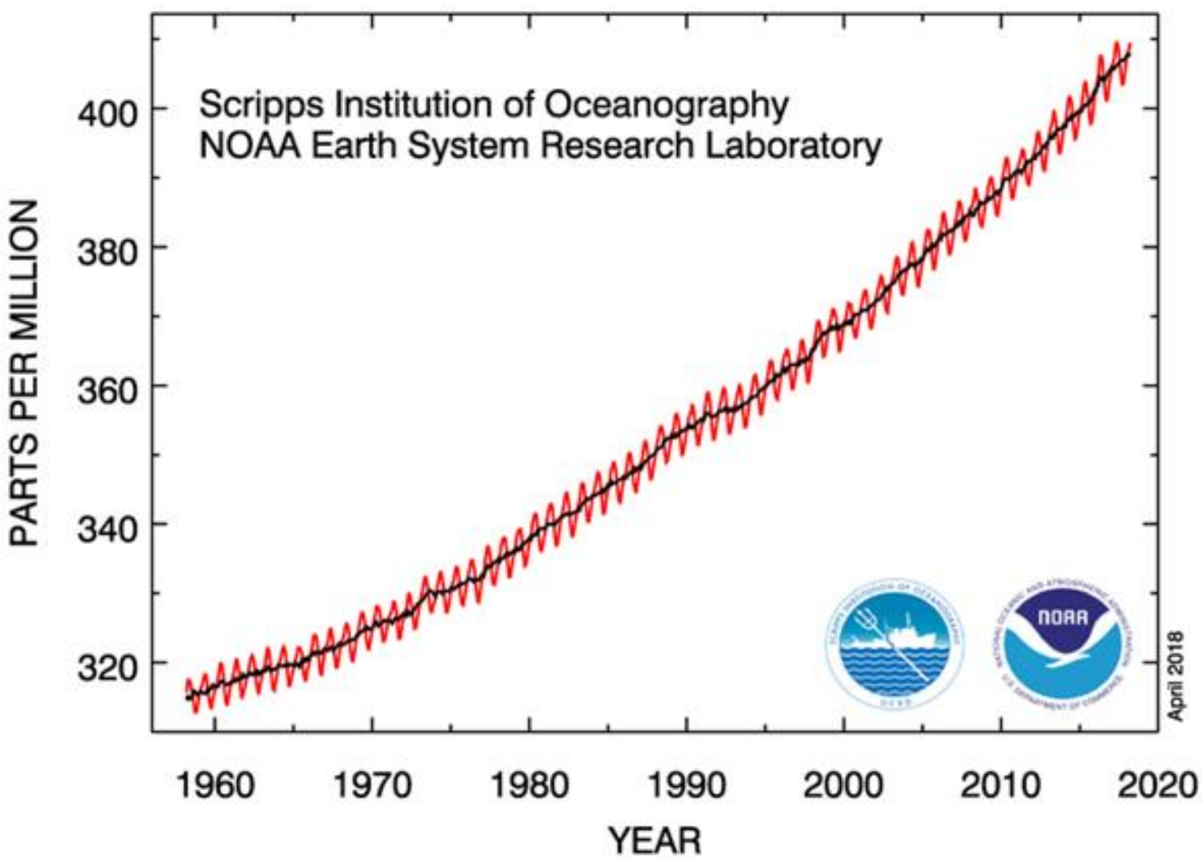


Figure 16. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawai`i from 1959-April 2018. Note: The red line shows monthly averages, and the black line shows seasonally corrected data.

Description: Monthly mean atmospheric carbon dioxide (CO_2) at Mauna Loa Observatory, Hawai`i 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 about one year. The annual oscillations at Mauna Loa, Hawai`i are due to the seasonal imbalance between the photosynthesis and respiration of plants on land. During the summer growing season photosynthesis exceeds respiration and CO_2 is removed from the atmosphere, whereas 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 this hemisphere's larger land mass.

Timeframe: Annual, monthly.

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

Data Source: "Full Mauna Loa CO_2 record" available at https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html. Data from additional monitoring stations, including the Tutuila, American Samoa station are available at https://www.esrl.noaa.gov/gmd/dv/iadv/.

Measurement Platform: *In-situ* station.

2.5.3.1.1 References

Keeling, C.D., Bacastow, R.B., Bainbridge, A.E., Ekdahl, C.A., Guenther, P.R., Waterman, L.S., 1976. Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii. *Tellus*, *28*, pp. 538-551.

Thoning, K.W., Tans, P.P., Komhyr, W.D., 1989. Atmospheric carbon dioxide at Mauna Loa Observatory 2. Analysis of the NOAA GMCC data, 1974-1985. *Journal of Geophysical Research*, *94*, pp. 8549-8565.

2.5.3.2 Oceanic pH

Rationale: Ocean 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 (indicated by lower oceanic pH) limits the ability of marine organisms to build shells and other hard structures. Recent research has shown that pelagic organisms such 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: Oceanic pH has shown a significant linear decrease of 0.0369 pH units, or roughly an 8.9% increase in acidity, over the nearly 30 years spanned by this time series. Additionally, the highest pH value reported for the most recent year (8.0846) is roughly equal to the lowest pH value reported in the first year of the time series (8.0845).

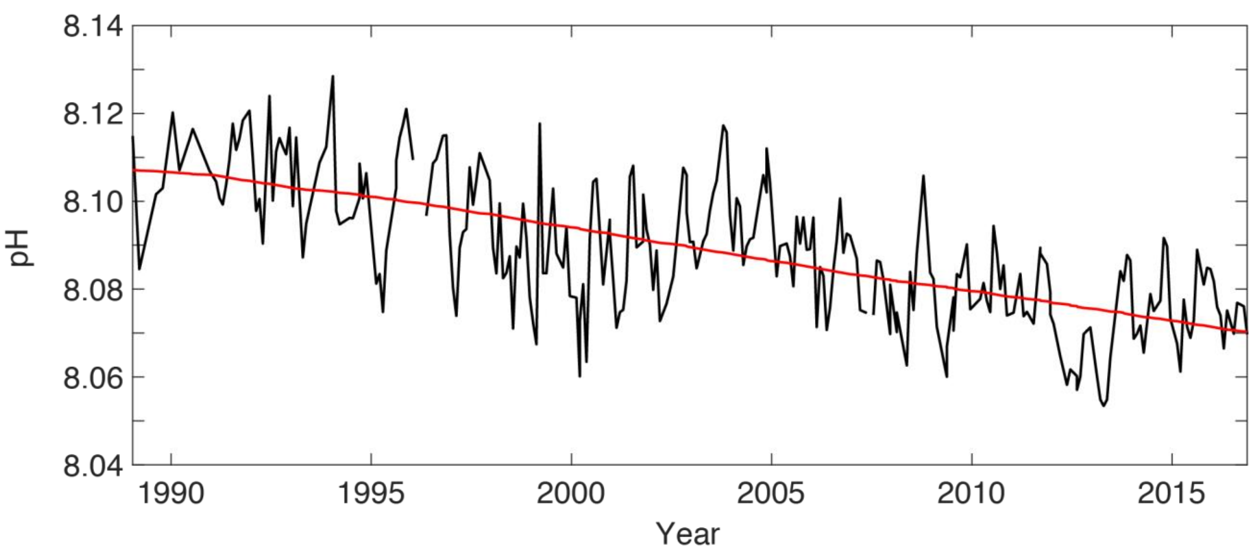


Figure 17. pH Trend at Station ALOHA, 1989 – 2016. **Note: Measured pH values are plotted in black. The linear fit to this time series is shown in red.**

Description: Trends in surface (5 m) pH at Station ALOHA, north of Oahu (22.75°N, 158°W), collected by the Hawai`i Ocean Time-series (HOT) from October 1988 to 2016 (2017 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. 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.

Data Source: Hawai`i Ocean Time-series at http://hahana.soest.hawaii.edu/hot/. The Hawai`i Ocean Time-series is maintained by the University of Hawai`i's School for Ocean and Earth Science and Technology.

Measurement Platform: *In-situ* station.

2.5.3.2.1 References

An overview of the relationship between acidity and pH can be found at: http://www.pmel.noaa.gov/co2/story/A+primer+on+pH

A detailed description of how HOT determines pH can be found at: http://hahana.soest.hawaii.edu/hot/methods/ph.html

Methods for calculating pH from TA and DIC can be found at: https://www.soest.hawaii.edu/oceanography/faculty/zeebe_files/CO2_System_in_Seawater/csys.html

Fabry, V.J., Seibel, B.A., Feely, R.A., Orr, J.C., 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, 65, pp. 414-432.

Feely, R.A., Alin, S.R., Carter, B., Bednarsek, N., Hales, B., Chan, F., Hill, T.M., Gaylord, B., Sanford, E., Byrne, R.H., Sabine, C.L., Greeley, D., Juranek, L., 2016. Chemical and biological impacts of ocean acidification along the west coast of North America. *Estuarine, Coastal and Shelf Science*, *183*, pp. 260-270. doi: 10.1016/j.ecss.2016.08.043.

2.5.3.3 Oceanic Niño Index

Rationale: The ENSO cycle is known to have impacts on Pacific fisheries targeting species including but not limited to tuna. The ONI focuses on ocean temperature, which has the most direct effect on these fisheries.

Status: The ONI was neutral in 2017.

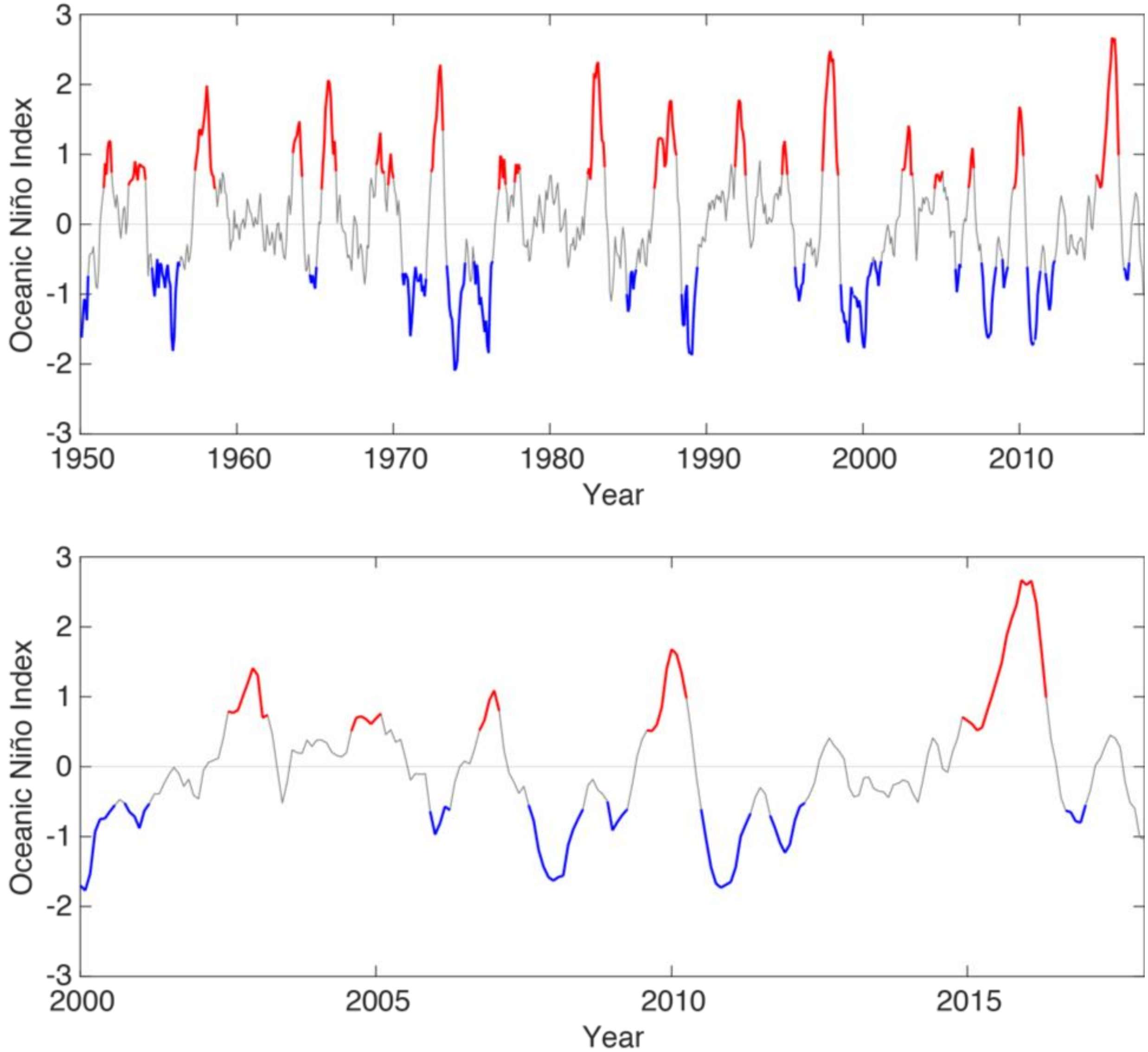


Figure 18. Oceanic Niño Index, 1950-2017 and 2000–2017. Note: Monthly time series of the Oceanic Niño Index for 1950 – 2017 (top) and 2000 – 2017 (bottom). El Niño periods are highlighted in red. La Niña periods are highlighted in blue.

Description: The three-month running mean of ERSST .v4 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 this Pacific basin oscillation is measured using the Southern Oscillation Index.

Timeframe: Quarterly.

Region/Location: Niño3.4 region: 5°S – 5°N, 120° – 170°W.

Data Source: NOAA NCEI at https://www.ncdc.noaa.gov/teleconnections/enso/indicators/sst.php.

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

2.5.3.3.1 References

A full description of ENSO and its global impacts can be found at: https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions.

2.5.3.4 Pacific Decadal Oscillation

Rationale: The Pacific Decadal Oscillation (PDO) was initially named by a 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 – 30 years versus 6 – 18 months for ENSO event. The climatic finger prints of the PDO are most visible in the Northeastern Pacific, but secondary signatures exist in the tropics.

Status: The PDO was positive, or warm, from January through June of 2017. For the remainder of the year, the PDO was negative, or cool. It remains to be seen whether the negative conditions during the second half of the year represent a short-term fluctuation or a true phase change.

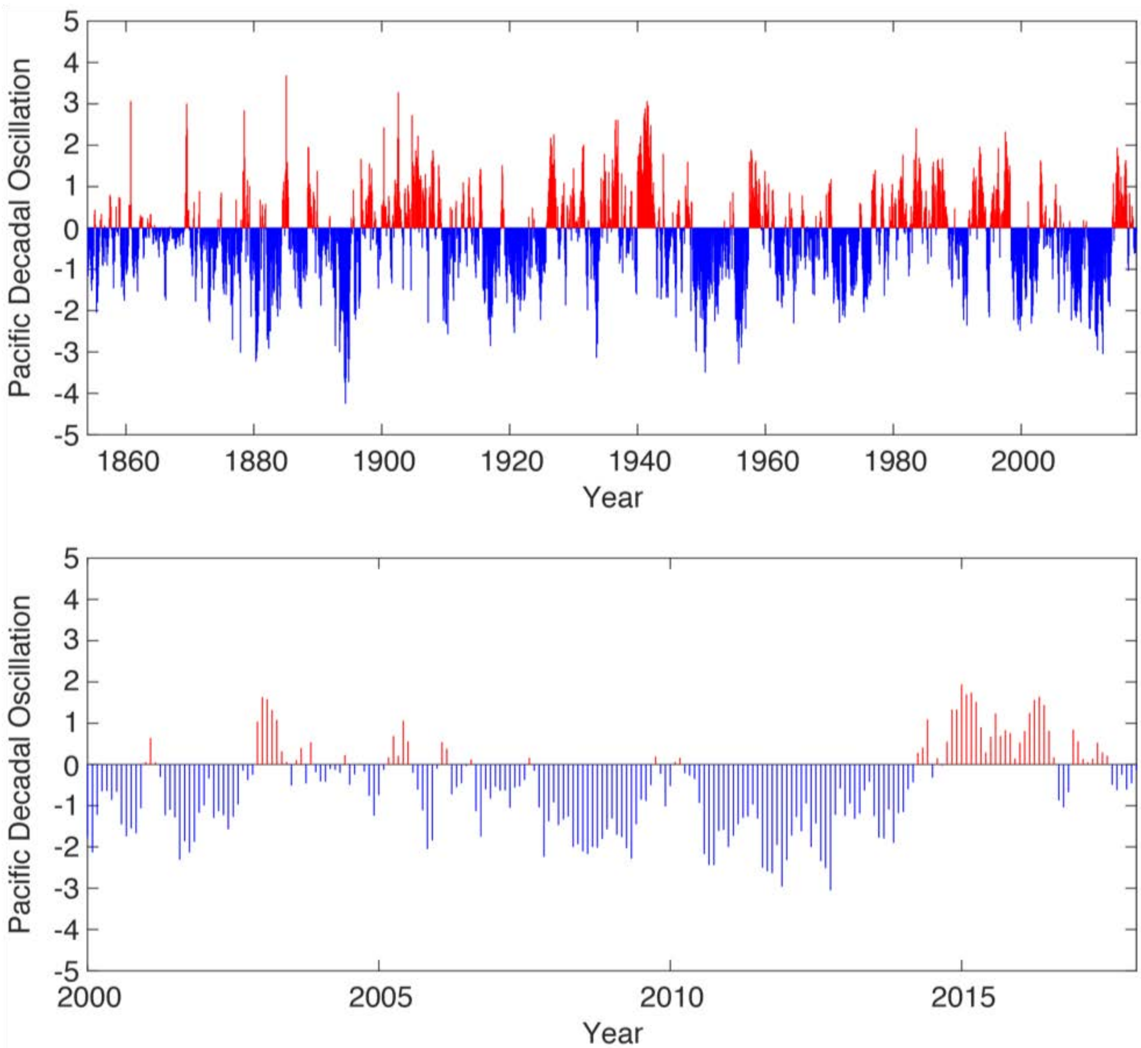


Figure 19. Pacific Decadal Oscillation, 1854–2017 and 2000–2017. Note: Monthly values of the Pacific Decadal Oscillation for 1854 – 2017 (top) and 2000 – 2017 (bottom). Positive, or warm, phases are plotted in red. Negative, or cool, phases are plotted in blue.

Description: The Pacific Decadal Oscillation (PDO) is often described as a long-lived El Niño-like pattern of Pacific climate variability. As seen with the better-known El Niño – Southern Oscillation (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 sea surface temperatures (SSTs) are anomalously cool in the interior 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 anomaly 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.

The National Centers for Environmental Information (NCEI) PDO index is based on NOAA's extended reconstruction of SST (ERSST v4; from https://www.ncdc.noaa.gov/teleconnections/pdo/).

Timeframe: Annual, monthly.

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

Data Source: NOAA NCEI at https://www.ncdc.noaa.gov/teleconnections/pdo/. NCEI is responsible for hosting and providing access to one of the most significant archives on Earth, with comprehensive oceanic, atmospheric, and geophysical data.

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

2.5.3.4.1 References

Mantua, N., 2000: The Pacific Decadal Oscillation. Available at http://research.jisao.washington.edu/pdo/. Accessed Feb. 2017.

2.5.3.5 Sea Surface Temperature & Anomaly

Description: Monthly sea surface temperature from 1982-2017, stitched together from three sources: (1) for 1982-2009 we use the Pathfinder v 5.0 dataset – a reanalysis of historical data from the Advanced Very High Resolution Radiometer (AVHRR); (2) to span 2010-2012 we use the AVHRR Global Area Coverage (GAC) dataset, and (3) data from 2013 to present we use the GOES-POES dataset, (see below for details). Both Pathfinder and GOES-POES provide 0.05º spatial resolution, while GAC provides 0.1º. A monthly climatology was generated across the entire period (1982-2017) to provide both a 2017 spatial anomaly, and an anomaly time series.

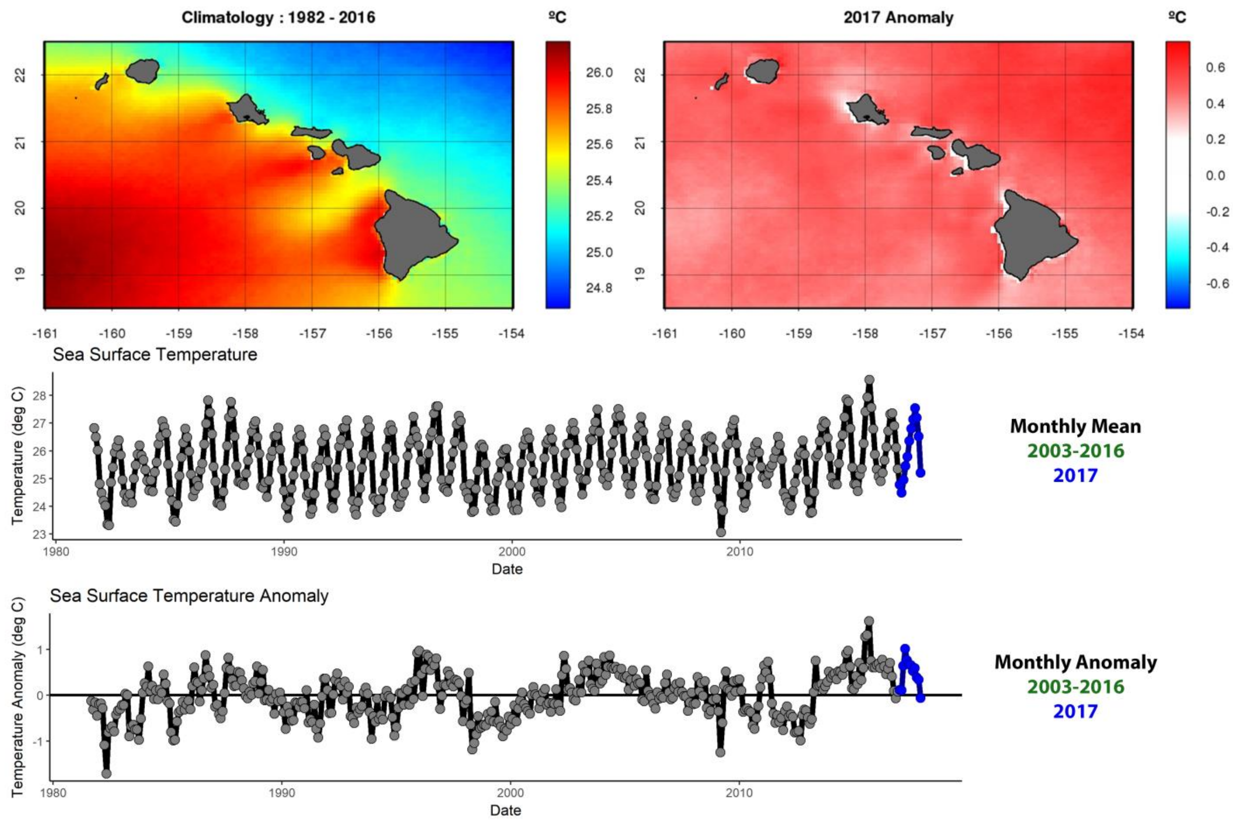


Figure 20. 2017 sea surface temperature (SST) and SST Anomaly.

Short Descriptions:

(1) The NOAA/NASA AVHRR Pathfinder v5 and v5.1 sea-surface temperature dataset is a reanalysis of historical AVHRR data that have been improved using extensive calibration, validation and other information to yield a consistent research quality time series for global climate studies. At 0.05 degrees per pixel (approximately 4 km/pixel), this dataset provides a global spatial coverage ranging from October 1981 - 2009. Our data holdings include descending passes (nighttime).

(2) The Advanced Very High Resolution Radiometer (AVHRR) satellite sensors onboard the NOAA POES (Polar-orbiting Operational Environmental Satellites) satellite constellation have been collecting sea-surface temperature (SST) measurements since 1981. This dataset combines

the NOAA/NASA AVHRR Pathfinder v4.1 dataset (January 1985 - January 2003) and the AVHRR Global Area Coverage (GAC) dataset (January 2003 - present) to provide a long time series of SST. These datasets are reduced-resolution legacy datasets and will be discontinued by NOAA in 2016. The dataset is composed of SST measurements from descending passes (nighttime). 3-day composites are only available for GAC, from 2003 - 2016.

(3) The GOES-POES dataset is a blended product, combining SST information from the Geostationary Operational Environmental Satellites (GOES) and the Polar-orbiting Operational Environmental Satellites (POES). This global SST analysis provides a daily gap-free map of the foundation sea surface temperature, generating high density SST data and improving the monitoring of small scale dynamic features in the coastal coral reef environment (text from the OceanWatch Central Pacific Node).

Pathfinder v5 & GAC datasets -

The 4 km Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 5 sea surface temperature (SST) dataset is a reanalysis of historical AVHRR data that have been improved using extensive calibration, validation and other information to yield a consistent research quality time series for global climate studies. This SST time series represents the longest continual global ocean physical measurement from space. Development of the Pathfinder dataset is sponsored by the NOAA National Oceanographic Data Center (NODC) in collaboration with the University of Miami Rosensteil School of Marine and Atmospheric Science (RSMAS) while distribution is a collaborative effort between the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) and the NODC. From a historical perspective, the Pathfinder program was originally initiated in the 1990s as a joint NOAA/NASA research activity for reprocessing of satellite based data sets including SST.
The AVHRR is a space-borne scanning sensor on the National Oceanic and Atmospheric Administration (NOAA) family of Polar Orbiting Environmental Satellites (POES) having an operational legacy that traces back to the Television Infrared Observation Satellite-N (TIROS-N) launched in 1978. AVHRR instruments measure the radiance of the Earth in 5 (or 6) relatively wide spectral bands. The first two are centered around the red (0.6 micrometer) and near-infrared (0.9 micrometer) regions, the third one is located around 3.5 micrometers, and the last two sample the emitted thermal radiation, around 11 and 12 micrometers, respectively. The legacy 5 band instrument is known as AVHRR/2 while the more recent version, the AVHRR/3 (first carried on the NOAA-15 platform), acquires data in a 6th channel located at 1.6 micrometer. Typically the 11 and 12 micron channels are used to derive SST sometimes in combination with the 3.5 micron channel. For the Pathfinder SST algorithm only the 11 and 12 micron channels are used. The NOAA platforms are sun synchronous generally viewing the same earth location twice a day (latitude dependent) due to the relatively large AVHRR swath of approximately 2400 km.
The highest ground resolution that can be obtained from the current AVHRR instruments is 1.1 km at nadir. (from https://podaac-www.jpl.nasa.gov/dataset/).

This particular dataset is produced from Global Area Coverage (GAC) data that are derived from an on-board sample averaging of the full resolution global AVHRR data. Four out of every five samples along the scan line are used to compute on average value and the data from only every third scan line are processed, yielding an effective 4 km resolution at nadir. The collection of

NOAA satellite platforms used in the AVHRR Pathfinder SST time series includes NOAA-7, NOAA-9, NOAA-11, NOAA-14, NOAA-16, NOAA-17, and NOAA-18. These platforms contain "afternoon" orbits having a daytime ascending node of between 13:30 and 14:30 local time (at time of launch) with the exception of NOAA-17 that has a daytime descending node of approximately 10:00 local time. SST AVHRR Pathfinder includes separate daytime and nighttime daily, 5 day, 8 day, monthly and yearly datasets. This particular dataset represent nighttime monthly averaged observations.

GOES-POES dataset -

The National Oceanic and Atmospheric Administration's Office of Satellite Data Processing and Distribution are generating operational sea surface temperature (SST) retrievals from the Geostationary Operational Environmental Satellite (GOES) 11 and 12 satellite imagers. They are situated at longitude 135^{o}W and 75^{o}W, respectively, thus allowing the acquisition of high-temporal-resolution SST retrievals.

A new cloud masking methodology based on a probabilistic (Bayesian) approach has been implemented for improved retrieval accuracy. This new GOES SST Bayesian algorithm provides SST retrievals with an estimate of the probability of cloud contamination. This indicates the confidence level of the cloud detection for the retrieval, which can be related to retrieval accuracy.

The GOES-11 and 12 imagers observe both northern and southern hemisphere every half an hour. These 5-band (0.6, 3.9, 6.7, 10.7, 12 or 13.3 micron) and 4-band (0.6, 3.9, 6.7, 10.7. or 13.3 micron) images are processed to retrieve SST retrievals at 4-km resolution. The window infrared channels determine the SST, and all channels (except the 6.7 and 13.3 μm) determine the cloud contamination. These retrievals are remapped, averaged, and composited hourly and posted to a server for user access. The retrievals are available approximately 90 minutes after the nominal epoch of the SST determinations. Three-hour and 24-hour averages are also made available. CoastWatch Regional Imagery is generated every three hours by combining the 1hourly SST images for these areas.(from *https://www.star.nesdis.noaa.gov/sod/mecb/blended_validation/background.php*).

Timeframe: 1982-2017, Daily data available, Monthly means shown.

Region/Location: Global.

Data Sources:

- “AVHRR Pathfinder v. 5 (ERDDAP Monthly)”

- “AVHRR GAC v. 5 (ERDDAP Monthly)”

- “GOES-POES v. 5 (ERDDAP Monthly)”

http://oceanwatch.pifsc.noaa.gov/doc.html.

Measurement Platform: AVHRR, POES Satellite, GOES 12 and 12 Satellites.

Rationale: Sea surface temperature is one of the most directly observable measures we have for tracking increasing ocean temperature.

2.5.3.5.1 References

Li, X., Pichel, W., Maturi, E., Clemente-Colón, P., and J. Sapper, J., 2001a. Deriving the operational nonlinear multi-channel sea surface temperature algorithm coefficients for NOAA-15 AVHRR/3. *Int. J. Remote Sens*., *22*(4), pp. 699-704.

Li, X, Pichel, W., Clemente-Colón, P., Krasnopolsky, V., and Sapper, J., 2001b. Validation of coastal sea and lake surface temperature measurements derived from NOAA/AVHRR Data. *Int. J. Remote Sens*., *22*(7), pp. 1285-1303.

Stowe, L.L., Davis, P.A., and McClain, E.P., 1999. Scientific basis and initial evaluation of the CLAVR-1 global clear/cloud classification algorithm for the advanced very high resolution radiometer. *J. Atmos. Oceanic Technol*., *16*, pp. 656-681.

Walton C.C., Pichel, W.G., Sapper, J.F., and May, D.A., 1998. The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites. *J. Geophys. Res*., *103*(C12), pp. 27999-28012.

2.5.3.6 Coral Thermal Stress Exposure: Degree Heating Weeks

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 a rolling sum of weekly thermal anomalies over a 12-week window. Higher DHW measures imply a greater likelihood of mass coral bleaching or mortality from thermal stress.

Short Description: 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. (from *the NOAA Coral Reef Watch* website).

Technical Summary: The NOAA Coral Reef Watch (CRW) experimental daily global 5km (0.05 degree) satellite coral bleaching heat stress monitoring product suite presented here is the third version (Version 3). The 5km suite is based on the NOAA/NESDIS operational daily global 5km geostationary-polar-orbiting (Geo-Polar) Blended Night-only SST Analysis. Current CRW 5km products include sea surface temperature (SST), SST Anomaly, Coral Bleaching Hotspots, Degree Heating Week (DHW), a 7-day maximum Bleaching Alert Area, and a 7-day SST Trend. CRW also has a 5km Regional Virtual Stations/Bleaching Heat Stress Gauges product and a free, automated 5km Bleaching Alert Email System that are based on this product suite (from *https://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php*).

A significantly improved climatology was introduced in the Version 3 products. It was derived from a combination of NOAA/NESDIS' 2002-2012 reprocessed daily global 5km Geo-Polar Blended Night-only SST Analysis and the 1985-2002 daily global 5km SST reanalysis, produced by the United Kingdom Met Office, on the Operational SST and Sea Ice Analysis (OSTIA) system. The near-real-time OSTIA SST was recently incorporated into the generation of NESDIS' operational daily 5km Blended SST that CRW's 5km coral bleaching heat stress monitoring product suite is based on. Hence, the 2002-2012 reprocessed 5km Geo-Polar Blended SST that has just become available, extended with the 1985-2002 portion of the 5km OSTIA SST reanalysis, is the best historical 1985-2012 global SST dataset for deriving a climatology that is internally consistent and compatible with CRW's near-real-time 5km satellite coral bleaching heat stress monitoring products. Although the reprocessed 5km Geo-Polar Blended SST dataset is available to the end of 2016, to be consistent with the time period (1985-2012) of the climatology used in our Version 2 5km product suite, the Version 3 climatology is based on the same time period. It was then re-centered to the center of the baseline time period of 1985-1990 plus 1993, using the method described in Heron *et al.*, (2015) and Liu *et al.*, (2014), and was based on our monitoring algorithm (also described in these articles). More recent years may be incorporated in the climatology for future versions of CRW's 5 km products, but potential impacts on the products require further evaluation first.

This Version 3 suite was released on May 4, 2017, along with a new version of CRW's 5km Regional Virtual Stations/Bleaching Heat Stress Gauges product. Version 2 of the 5km product suite (that Version 3 replaces) was released on May 5, 2014, and Version 1 was released on July 5, 2012 (based on NESDIS' operational daily global 5 km Geo-Polar Blended Day-Night SST Analysis and an earlier version of the climatology derived from the PFV5.2).

Development of this next-generation 5 km product suite was accomplished through a collaboration of NOAA Coral Reef Watch, the University of South Florida, NASA-Ames, the UNEP World Conservation Monitoring Centre, and the Cooperative Institute for Research in Environmental Science, with funding support from the NASA Biodiversity and Ecological Forecasting program, the NOAA Coral Reef Conservation Program, and the NOAA/NESDIS Ocean Remote Sensing Program. Production of the Version 3 suite was made possible through funding from the NOAA Coral Reef Conservation Program. The 5km product suite, which was featured in the NASA Applied Sciences Program's 2013 Annual Report, will undergo continuous improvements.

Regional Virtual Stations Product Description: NOAA Coral Reef Watch (CRW) has developed a set of experimental 5 km Regional Virtual Stations (213 total).

NOAA CRW also expanded the geographic network of 5 km Virtual Stations to include all coral reefs around the world, based on available references. These included the Millennium Coral Reef project maps, the IUCN Coral Reefs of the World three-volume set, the UNEP/WCMC World Atlas of Coral Reefs, several country scale atlas publications, and a few other resources. These references were also used to develop the outline (in black) for each 5 km Regional Virtual Station. Each Virtual Station outline is based on a global 5 km reef pixel mask developed by NOAA CRW, with the addition of a 20 km buffer around each 5 km reef mask.

Timeframe: 2013-2017, Daily.

Region/Location: Global.

Data Source: “NOAA Coral Reef Watch” https://coralreefwatch.noaa.gov

Measurement Platform: NOAA/NESDIS operational daily global 5km geostationary-polar-orbiting (Geo-Polar) Blended Night-only SST Analysis

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

2.5.3.6.1 References

Liu, G., Heron, S.F., Eakin, C.M., Muller-Karger, F.E., Vega-Rodriguez, M., Guild, L.S., De La Cour, J.L., Geiger, E.F., Skirving, W.J., Burgess, T.F. and Strong, A.E., 2014. Reef-scale

thermal stress monitoring of coral ecosystems: new 5-km global products from NOAA Coral Reef Watch. *Remote Sensing*, *6*(11), pp.11579-11606.

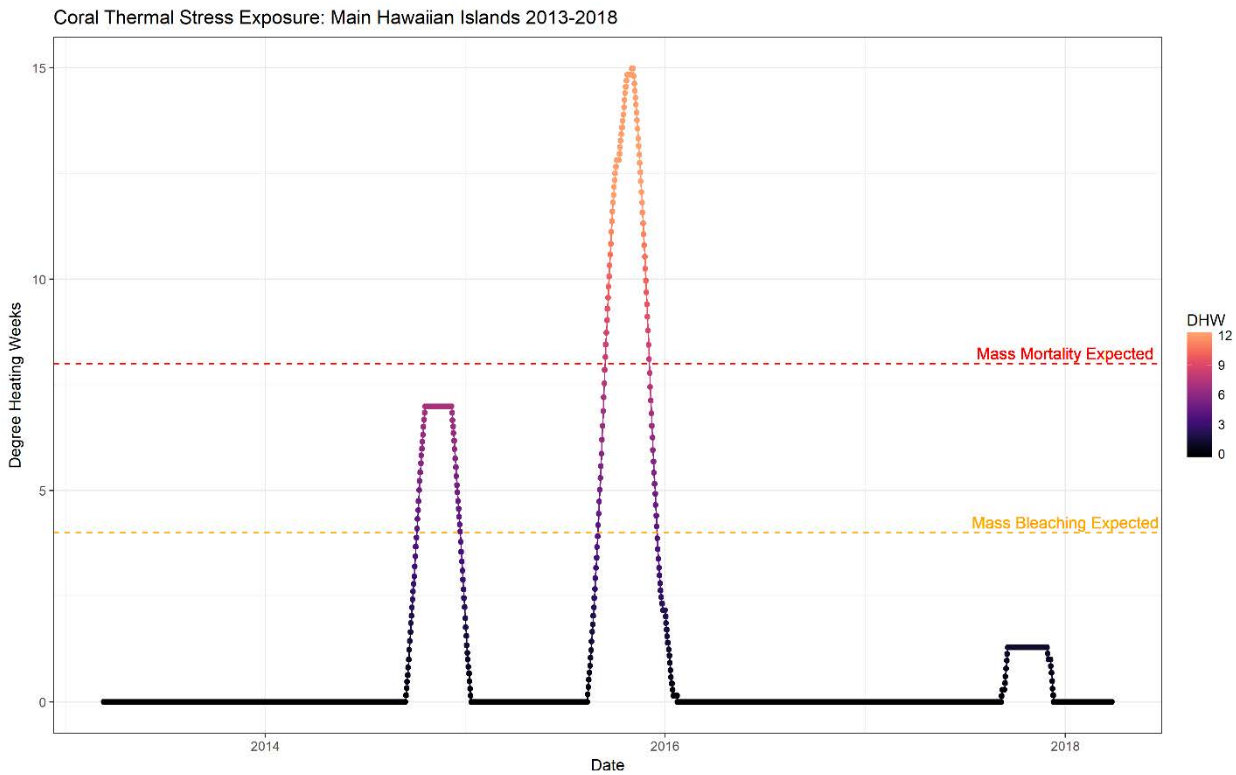


Figure 21. Coral Thermal Stress Exposure, Main Hawaiian Island Virtual Station from 2013-2017, measured in Coral Reef Watch Degree Heating Weeks.

2.5.3.7 Chlorophyll-A and Anomaly

Description: Chlorophyll-A Concentration from 2002-2017, derived from the MODIS Ocean Color sensor aboard the NASA Aqua Satellite. A monthly climatology was generated across the entire period (1982-2017) to provide both a 2017 spatial anomaly, and an anomaly time series.

Short Description: The MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor was deployed onboard the NASA Aqua satellite. It is a multi-disciplinary sensor providing data for the ocean, land, aerosol, and cloud research and is used for detecting chlorophyll-a concentrations in the world's oceans, among other applications. Aqua MODIS views the entire Earth's surface every 2 days, acquiring data in 36 spectral bands. The data available here is the latest reprocessing from June 2015, which NASA undertook to correct for some sensor drift issues (from *OceanWatch Central Pacific Node*).

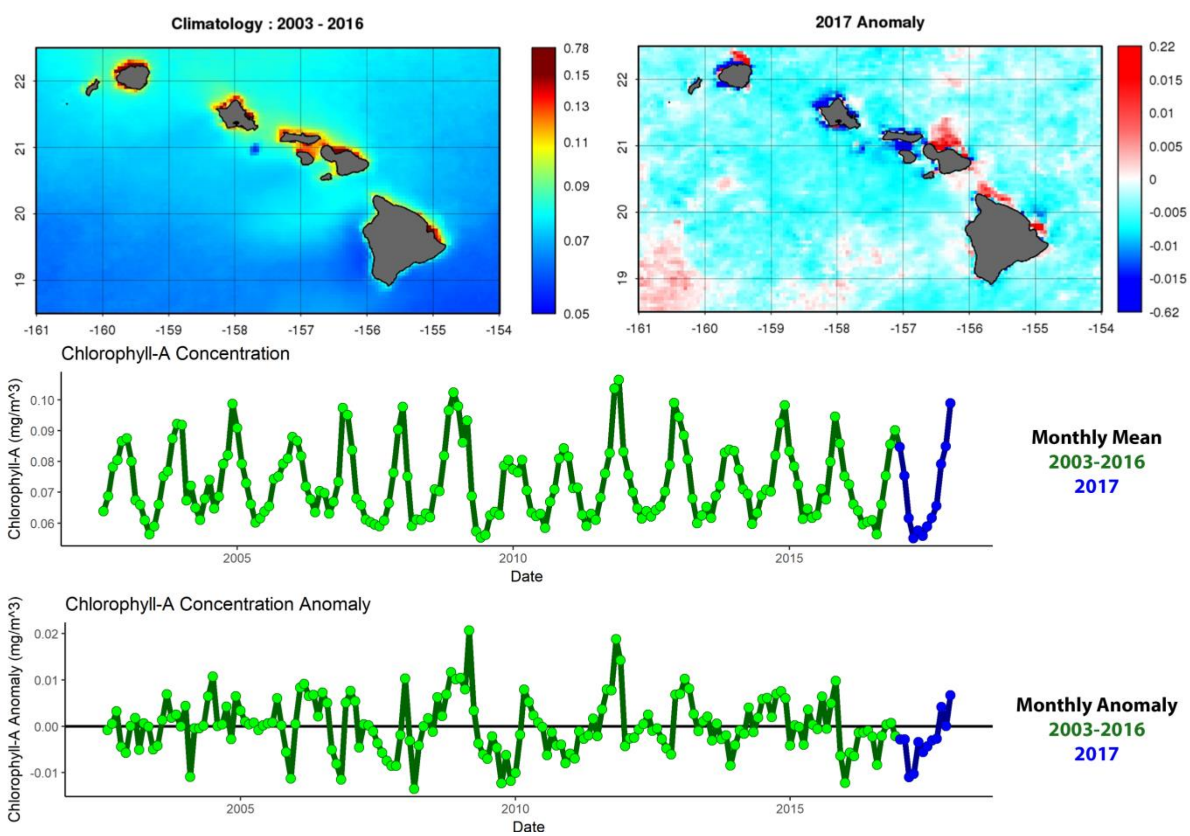


Figure 22. Chlorophyll-A monthly means and anomalies.

Technical Summary: The Moderate-resolution Imaging Spectro-radiometer (MODIS) is a scientific instrument (radiometer) launched by NASA in 2002 on board the Aqua satellite platform (a second series is on the Terra platform) to study global dynamics of the Earth's atmosphere, land and oceans. MODIS captures data in 36 spectral bands ranging in wavelength from 0.4 um to 14.4 um and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). The Aqua platform is in a sun synchronous, near polar orbit at 705 km altitude and the MODIS instrument images the entire Earth every 1 to 2 days. The Level 3 standard mapped image (SMI) chlorophyll-a dataset has a monthly temporal resolution and 4.6

km (at the equator) spatial resolution. The SMI dataset is an image representation of binned MODIS data (more detailed information on the SMI format can be found at http://oceancolor.gsfc.nasa.gov). The MODIS Aqua instrument provides quantitative data on global ocean bio-optical properties to examine oceanic factors that affect global change and to assess the oceans' role in the global carbon cycle, as well as other biogeochemical cycles. Subtle changes in chlorophyll-a signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications. This is a local dataset derived from the NASA Ocean Biology Processing Group (OBPG) meant to expose these data to tools and services at the PO.DAAC (from *https://podaac-www.jpl.nasa.gov/dataset/MODIS_Aqua_L3_CHLA_Monthly_4km_V2014.0_R*).

Timeframe: 2003-2017, Daily data available, Monthly means shown.

Region/Location: Global.

Data Source: MODIS-Aqua ERDDAP Monthly from http://oceanwatch.pifsc.noaa.gov/doc.html

Measurement Platform: MODIS sensor on NASA Aqua Satellite

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

2.5.3.7.1 References

Savtchenko, A., Ouzounov, D., Ahmad, S., Acker, J., Leptoukh, G., Koziana, J. and Nickless, D., 2004. Terra and Aqua MODIS products available from NASA GES DAAC. *Advances in Space Research*, *34*(4), pp. 710-714.

2.5.3.8 Heavy Weather (Tropical Cyclones & Storm-Force Winds)

Description: This indicator uses historical data from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) International Best Track Archive for Climate Stewardship (IBTrACS; Knapp *et al.,* 2010) to track the number of tropical cyclones in the western, central, and south Pacific basins. This indicator also monitors the Accumulated Cyclone Energy (ACE) Index, one way of monitoring the strength and duration of tropical cyclones based only on wind speed measurements.

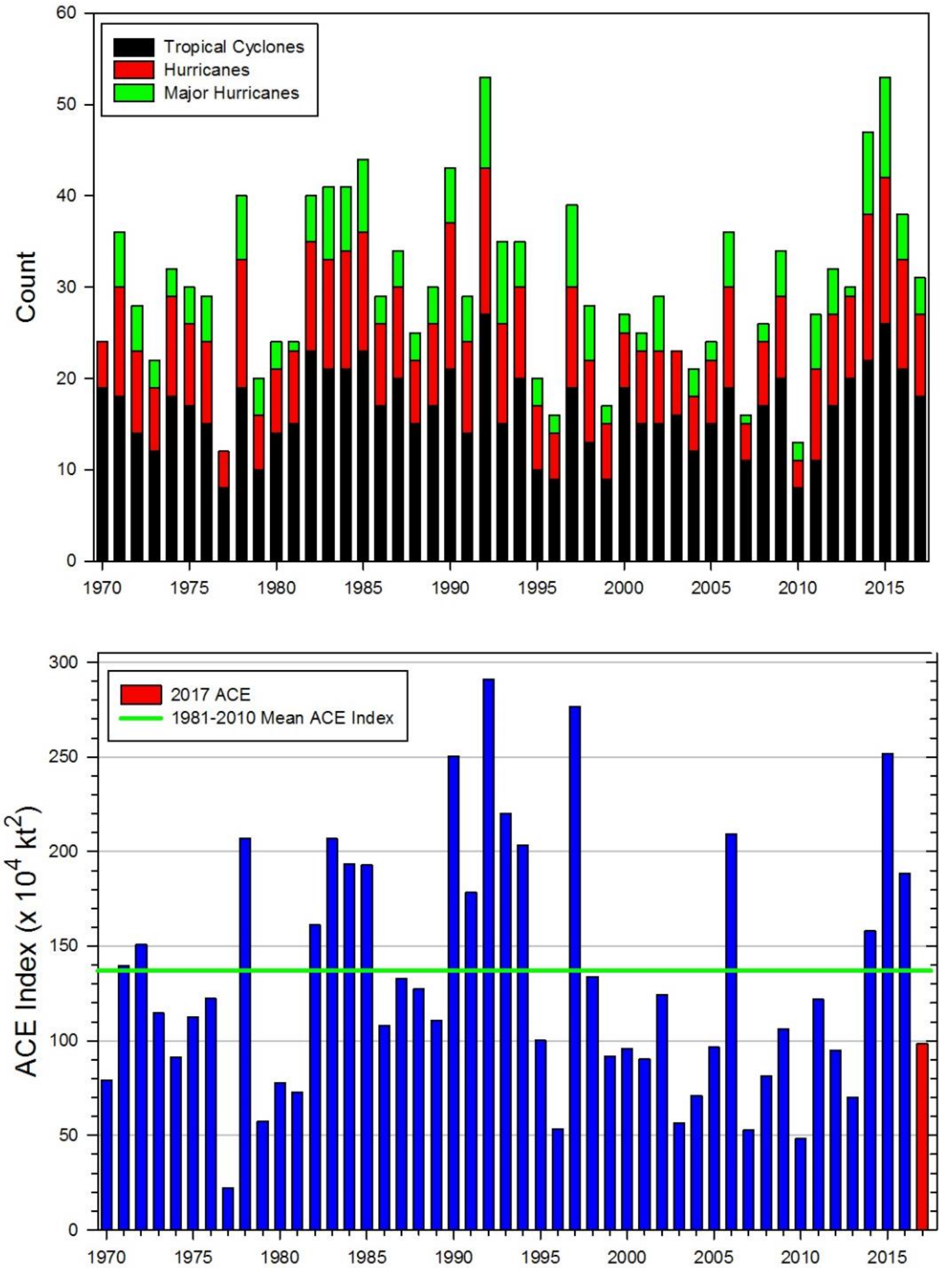


Figure 23. Annual Patterns of Tropical Cyclones in the Eastern Pacific, 1970-2017, with 1981-2010 mean superimposed.

The annual frequency of storms passing through the Pacific basin is tracked and a stacked time series plot shows the representative breakdown of the Saffir-Simpson hurricane categories. Three solid color groups in the graph represent a) the annual number of named storms, b) the annual number of typhoons, and c) the annual number of major typhoons (Cat. 3 and above).

Every cyclone has an ACE Index value, which is a computed value 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 knot; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. This plot shows the historical ACE values for each typhoon season and has a solid line representing the 1981-2010 average ACE value.

In addition, we also plot the percentage occurrence of "storm-force" winds, wind occurrences greater than, or equal to, 34 knots since 1980 in the three sub-regions. The value of 34 knots represents "Gale, fresh gale" on the Beaufort scale, which corresponds to 5-8 m wave heights and boating becomes very challenging. Characterizing the percent occurrence of these gale-force winds gives an indication of storminess5 frequency within each sub-region. Indeed, slight increases in the frequency of gale-force winds are noted in both the South and Western Pacific basins, while a downward trend is evident in the Central Pacific. (Marra *et al.,* 2017)

Timeframe: Yearly

Region/Location: Hawaii and U.S. Affiliated Pacific Islands

Data Source/Responsible Party: NCEI's International Best Track Archive for Climate Stewardship (IBTrACS).

Measurement Platform: Satellite

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 Hawaii longline fishery, for example, had serious problems between August and November 2015 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. The associated storm surge, the large volume of ocean water pushed toward shore by the cyclone's strong winds, can cause severe flooding and destruction.

Neither the Pacific ENSO Applications Climate Center nor the Bulletin of the AMS has yet published their annual tropical cyclone report covering the central or south pacific in 2017.

While reports on activity during 2017 are not yet available for the south and central pacific, the NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, notes that "The 2017 East Pacific hurricane season had 18 named storms, including nine hurricanes, four of which became major." The 1981-2010 average number of named storms in the East Pacific was 16.5, with 8.9 hurricanes, and 4.3 major hurricanes. Five Eastern Pacific tropical cyclones made landfall in 2017. Tropical Storm Selma made landfall in El Salvador and tropical storms Beatrix, Calvin, Lidia and Hurricane Max made landfall in Mexico. Tropical Storm Selma was the first named tropical cyclone on record to make landfall in El Salvador. Tropical Storm Adrian formed on May 9th, marking the earliest occurrence of a named storm in the East Pacific basin. The previous earliest occurrence was Tropical Storm Alma forming on May 12, 1990. For the first year since 2012 no tropical cyclones passed near the Hawaiian Islands. The ACE index for the East Pacific basin during 2016 was 98 (x10^4 knots^2), which is below the 1981-2010 average of 132 (x10^4 knots^2), and the lowest since 2013" (from https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713).

2.5.3.8.1 References

NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2017, published online January 2018, retrieved on March 30, 2018 from http://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713.

Kanamitsu, M., Ebisuzaki, W., Woollen, J., Yang, S.K., Hnilo, J.J., Fiorino, M., and Potter, G.L., 2002. NCEPDOE AMIP-II Reanalysis (R-2). *Bull. Am. Met. Soc.*, *83*, pp. 1631-1643. https://doi.org/10.1175/BAMS-83- 11-1631.

Knapp, K.R., Kruk, M.C., Levinson, D.H., Diamond, H.J., and Neumann, C.J., 2010. The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, *91*, pp. 363-376. doi:10.1175/2009BAMS2755.1.

State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate, 2017. Coordinating Authors: J.J. Marra and M.C. Kruk. Contributing Authors: M. Abecassis; H. Diamond; A. Genz; S.F. Heron; M. Lander; G. Liu; J. T. Potemra; W.V. Sweet; P. Thompson; M.W. Widlansky; and P. Woodworth-Jefcoats. NOAA NCEI.

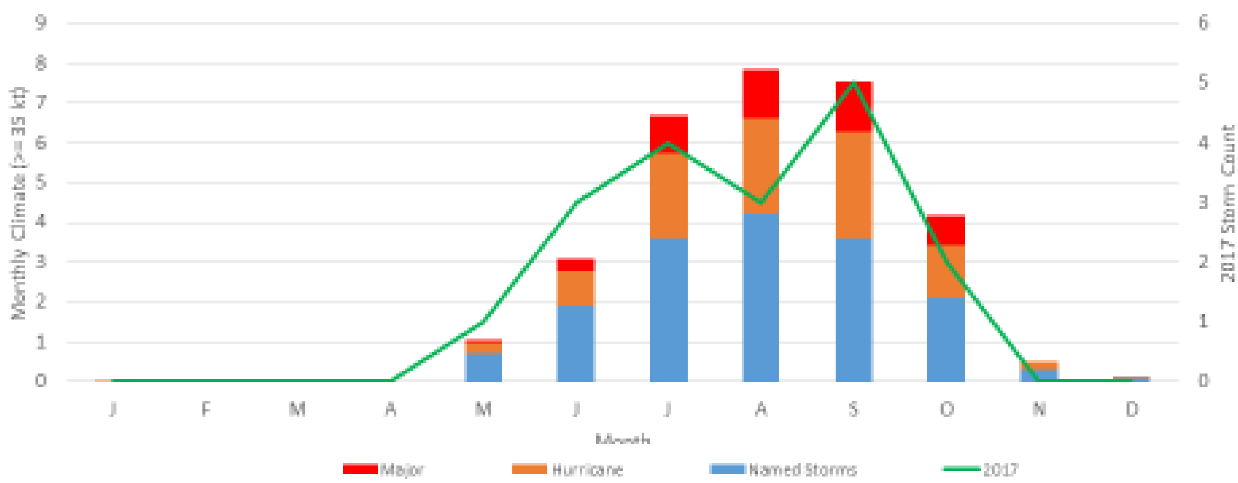


Figure 24. Seasonal Climatology of Tropical Cyclones in the Eastern Pacific, 1981-2010, with 2017 storms superimposed in green.

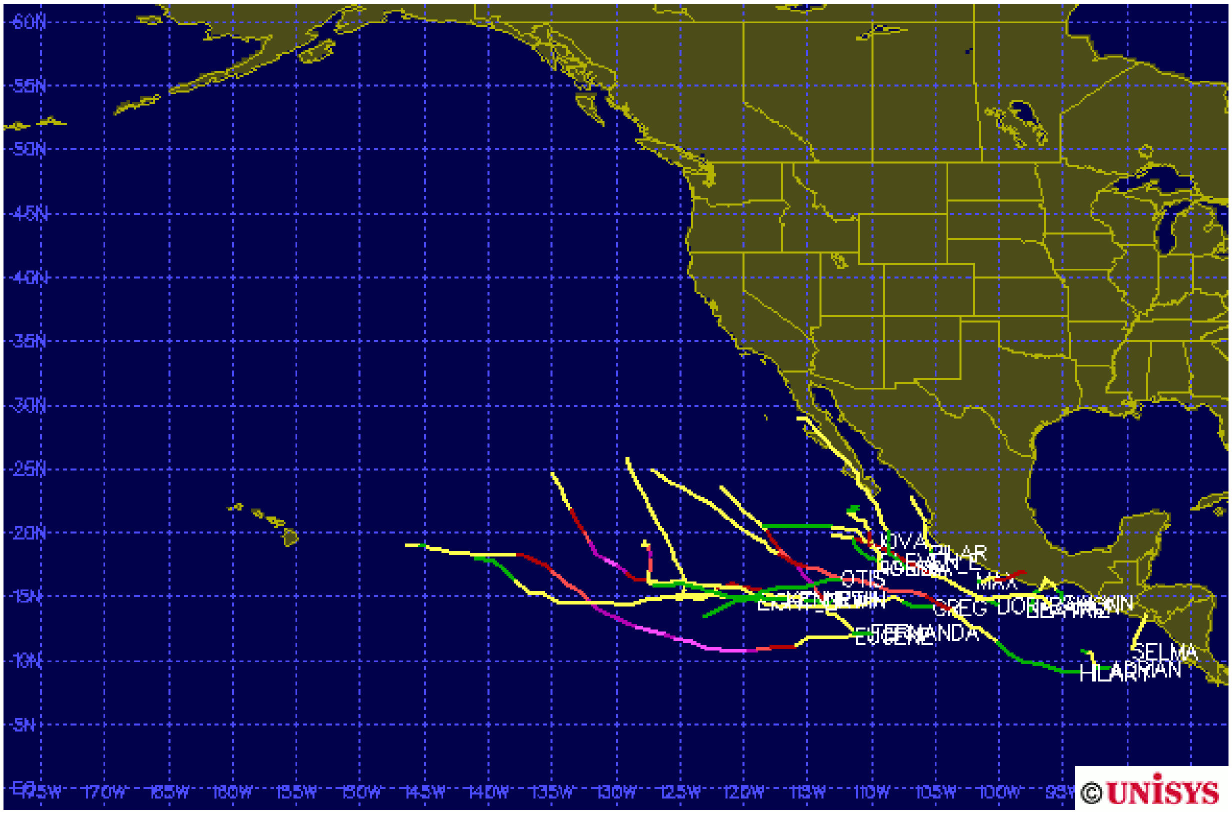


Figure 25. Eastern Pacific Cyclone Tracks in 2017.

2.5.3.9 Rainfall (CMAP Precipitation)

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 (infrared and microwave). The analyses are on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979. These data are comparable (but should not be confused with) similarly combined analyses by the Project, which are described in Huffman *et al*. (1997).

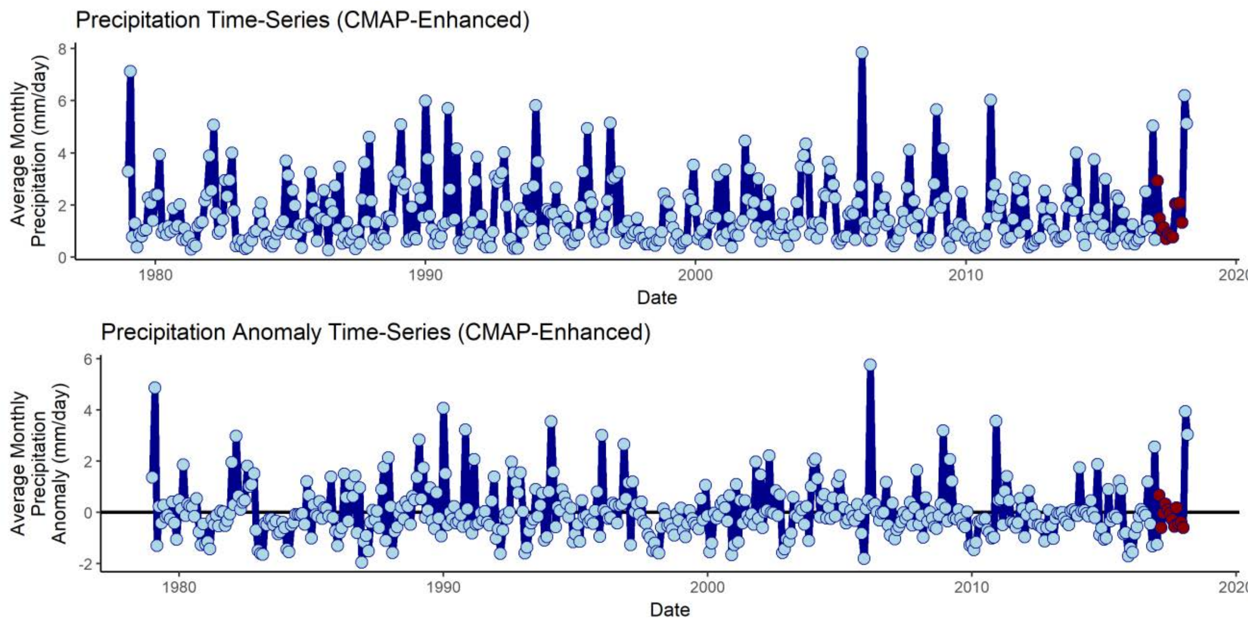


Figure 26. CMAP precipitation across the Main Hawaiian Islands Grid. 2017 values in red.

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 of 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 polar 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). Here the data output from step 1 is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude.

Monthly and pentad CMAP estimates back to the 1979 are available from CPC ftp server (from *http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.html*).

The monthly data set consists of two files containing monthly averaged precipitation rate values. Values are obtained from 5 kinds of satellite estimates (GPI,OPI,SSM/I scattering, SSM/I emission and MSU) and gauge data. The enhanced file also includes blended NCEP/NCAR Reanalysis Precipitation values (from *https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html#detail*).

Timeframe: Monthly.

Region/Location: Global.

Data Source: CMAP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/.

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

2.5.3.9.1 References

Xie, P. and Arkin, P.A., 1997. Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, *78*, pp. 2539 - 2558.

Huffman, G.J., Adler, R.F., Arkin, P., Chang, A., Ferraro, R., Gruber, A., Janowiak, J., McNab, A., Rudolf, B. and Schneider, U., 1997. The global precipitation climatology project (GPCP) combined precipitation dataset. *Bull. Amer. Meteor. Soc.*, *78*(1), pp.5-20.

Reynolds, R.W., 1988. A real-time global sea surface temperature analysis. *J. Climate*, *1*, pp. 75-86.

Spencer, R.W., 1993. Global oceanic precipitation from the MSU during 1979-91 and comparisons to other climatologies. *J. Climate*, *6*, pp. 1301-1326.

Xie P. and Arkin, P.A., 1997. Global precipitation: a 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, *78*, pp. 2539-2558.

2.5.3.10 Sea Level (Sea Surface Height and Anomaly)

Description: Monthly mean sea level time series, including extremes.

Timeframe: Monthly.

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

Data Source/Responsible Party: Basin-wide context from satellite altimetry:
http://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/el-nino-bulletin.html

Quarterly time series of mean sea level anomalies from satellite altimetry:
http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2015

Sea Surface Height and Anomaly from NOAA Ocean Service, Tides and Currents, Sea Level Trends: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000

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

Rationale: 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.

2.5.3.10.1 Basin-Wide Perspective

This image of the mean sea level anomaly for February 2016 compared to 1993-2013 climatology from satellite altimetry provides a glimpse into how the 2015-2016 El Niño continues to affect sea level across the Pacific Basin. The image captures the fact that sea level continues to be lower in the Western Pacific and higher in the Central and Eastern Pacific (a standard pattern during El Niño events; this basin-wide perspective provides a context for the location-specific sea level/sea surface height images that follow).

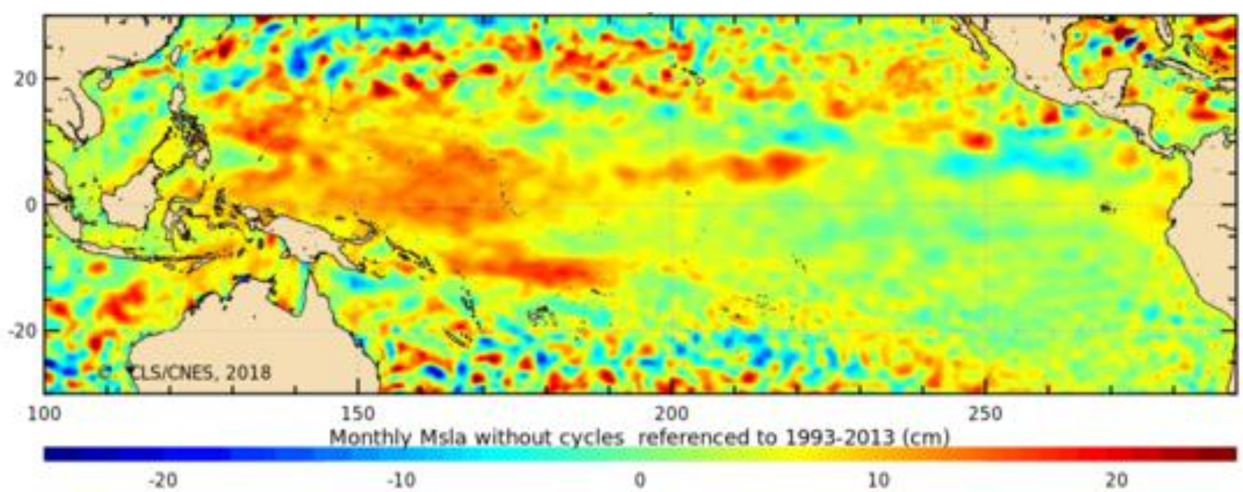
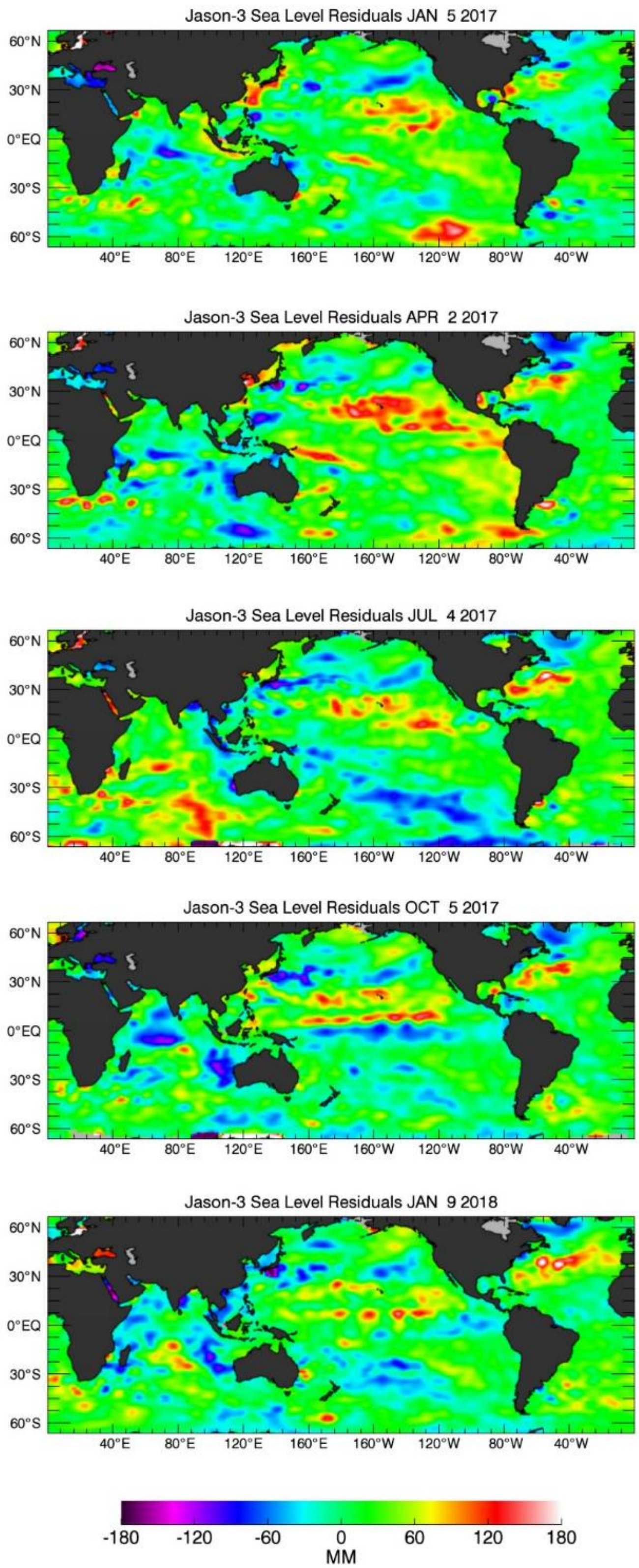
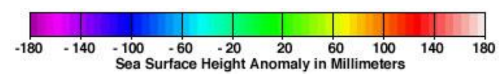


Figure 27a. Sea surface height and anomaly, February 2018.



27b. Quarterly time series of mean sea level anomalies during 2017 show no pattern of El Niño throughout the year according to satellite altimetry measurements of sea level height.

(from http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2017).



2.5.3.10.2 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/COOPS).

The following figures and descriptive paragraphs were inserted from https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1612340.

Figure 28 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

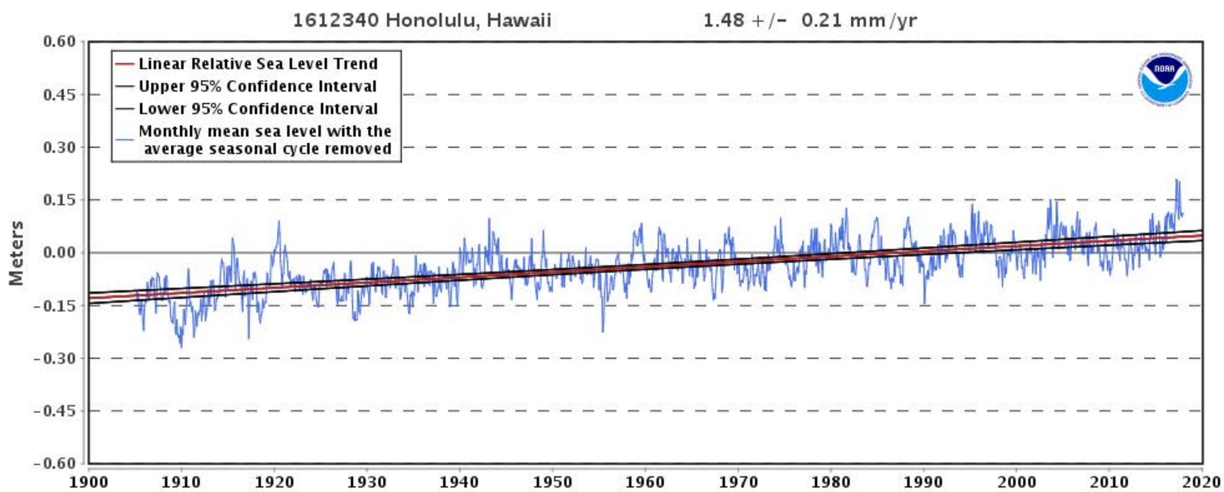


Figure 28. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

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 (0.3 meters = 1 foot). 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 monthly extreme water levels include a Mean Sea Level (MSL) trend of 1.48 millimeters/year with a 95% confidence interval of +/- 0.21 millimeters/year based on monthly MSL data from 1905 to 2017 which is equivalent to a change of 0.49 feet in 100 years.

2.6 ESSENTIAL FISH HABITAT

2.6.1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act 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 Magnuson-Stevens Act defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Habitat Areas of Particular Concern (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.

The National Marine Fisheries Service (NMFS) and regional Fishery Management Councils (Councils) must describe and identify EFH in fishery management plans (FMPs), 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.

The EFH Final Rule strongly recommends regional fisheries management councils and NMFS to conduct a review and revision of the EFH components of fisheries management plans every 5 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 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.

2.6.1.1 EFH Information

The EFH components of the FMPs include the identification and description of EFH, lists of prey species and locations for each managed species, and optionally, habitat areas of particular concern (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 SAFE report.

The Council has described EFH for five management unit species (MUS) under its management authority: pelagic (PMUS), bottomfish (BMUS), crustaceans (CMUS), coral reef ecosystem (CREMUS), and precious corals (PCMUS). The Hawaii FEP describes EFH for the BMUS, CMUS, CREMUS, 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 Section 2.6.2.
- Updated research and information needs, which can be found in Section 2.6.5. These can be used to directly update the FEP.
- 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.

2.6.1.2 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.

This annual report reviews the precious coral 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.

2.6.1.3 Response to Previous Council Recommendations

At its 170th meeting, the Council directed staff to develop options for refining precious coral's EFH for Council consideration based on the 2016 SAFE report EFH review. The options paper is under development.

Also at its 170th meeting, the Council directed staff to scope the non-fishing impacts review from the 2016 SAFE reports through its advisory bodies. The Hawaii Regional Ecosystem Advisory Committee provided comments on the non-fishing impacts review at a meeting held December 1, 2017, in Honolulu, Hawaii.

2.6.2 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 more shallow reef habitat overall.

EFH in the Hawaiian Archipelago for the four 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 exclusive economic zone (EEZ). While 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 Program (CREP) biennially since 2002, surveys are focused on the nearshore environments surrounding the islands, atolls, and reefs (PIBHMC).

The mission of the PIFSC CREP is to “provide high-quality, scientific information about the status of coral reef ecosystems of the U.S. Pacific islands to the public, resource managers, and policymakers on local, regional, national, and international levels” (PIFSC, 2011). CREP’s Reef Assessment and Monitoring Program (RAMP) conducts comprehensive ecosystem monitoring surveys at about 50 island, atoll, and shallow bank sites in the Western Pacific region on a one- to three-year schedule (PIFSC, 2008). CREP coral reef monitoring reports provide the most comprehensive description of nearshore habitat quality in the region. The benthic habitat mapping program provides information on the quantity of habitat.

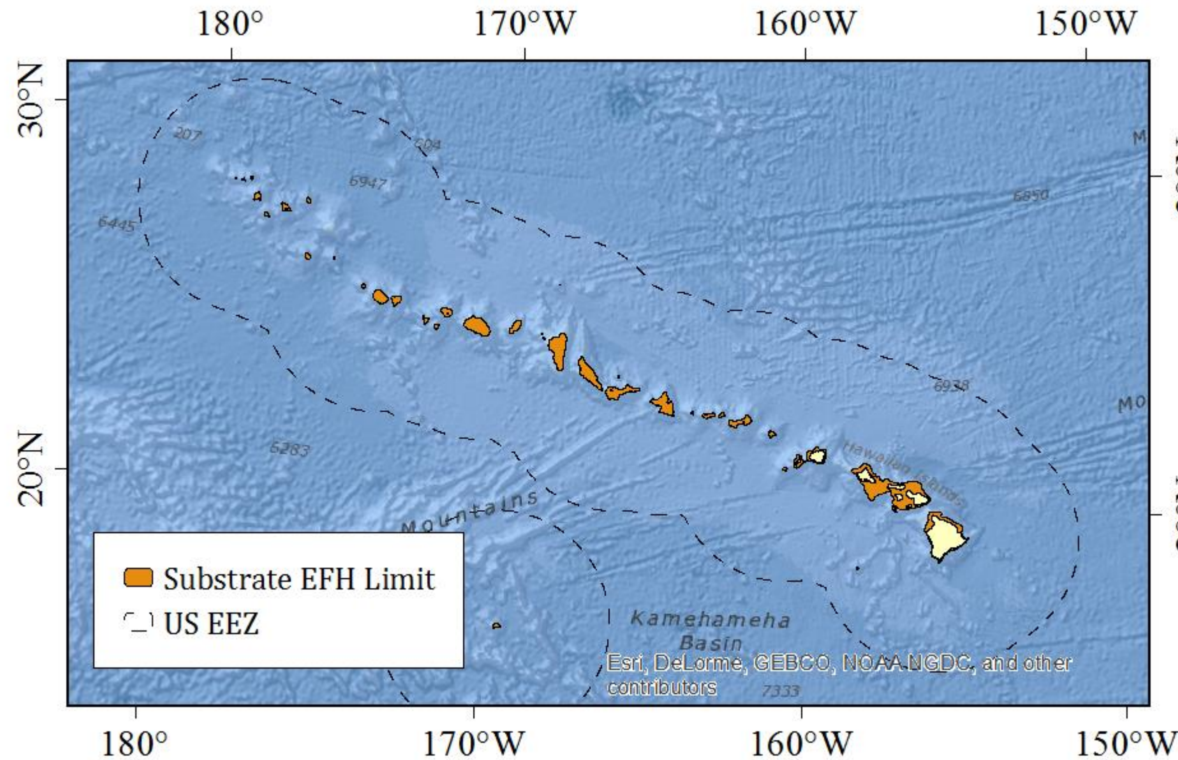


Figure 29. Substrate EFH limit of 700 m isobath around the islands and surrounding banks of the Hawaiian Archipelago.

2.6.2.1 Habitat Mapping

Interpreted IKONOS benthic habitat maps in the 0 – 30 m depth range have been completed for all islands in the MHI and NWHI (CRCP, 2011). While there are gaps in multibeam coverage in the MHI (CRCP, 2011), 60 m resolution bathymetry and backscatter are available from the Falkor for much of the NWHI (MHI Multibeam Bathymetry and Backscatter Synthesis).

Table 65. Summary of habitat mapping in the MHI.

Depth Range	Timeline/Mapping Product	Progress	Source
0-30 m	IKONOS Benthic Habitat Maps	All islands complete	CRCP, 2011
	2000-2010 Bathymetry	84%	DesRochers, 2016
	2011-2015 Multibeam Bathymetry	4%	DesRochers, 2016
	2011-2015 Satellite WorldView 2 Bathymetry	5%	DesRochers, 2016
0-150 m	Multibeam Bathymetry	Gaps exist around Maui, Lanai, and Kahoolawe.	CRCP, 2011

		Access restricted at Kahoolawe.	
30-150 m	2000-2010 Bathymetry	86%	DesRochers, 2016
	2011-2015 Multibeam Bathymetry	2%	DesRochers, 2016
Over all multibeam depths	Derived Products	Few exist	CRCP, 2011

Table 66. Summary of habitat mapping in the NWHI.

Depth Range	**Timeline/Mapping Product**	**Progress**	**Source**
0-30 m	IKONOS Benthic Habitat Maps	All islands complete	CRCP, 2011
	2000-2010 Bathymetry	6%	DesRochers, 2016
	2011-2015 Multibeam Bathymetry	-	DesRochers, 2016
	2011-2015 Satellite WorldView 2 Bathymetry	-	DesRochers, 2016
30-150 m	2000-2010 Bathymetry	49%	DesRochers, 2016
	2011-2015 Multibeam Bathymetry	4%	DesRochers, 2016

The land and seafloor area surrounding the islands of the MHI as well as primary data coverage are reproduced from CRCP (2011) in Figure 30. The land and seafloor area surrounding the islands of the NWHI as well as primary data coverage are similarly reproduced in Figure 31.

ISLAND CODE	KAL	NII	KAU	OAH	MOL	LAN	MAI	MOI	KAH	NUI	HAW
SHAPE & RELATIVE SIZE											
LAND AREA (km²)	<1	187	1437	1549	670	365	1886	<1	116		10442
SEA FLOOR AREA 0-30 m (km²)	3	108	242	423	199	55	197	?	4		202
SEA FLOOR AREA 30-150 m (km²)	62	182	297	467	*	*	*	*	*	2801	699
BATHYMETRY 0-30 m (km²)	0	41	237	422	144	17	178	?	0		134
BATHYMETRY 30-150 m (km²)	19	181	292	454	*	*	*	*	*	2346	584
OPTICAL COVERAGE 0-30 m (km)	4	41	45	44	30	32	66	1	0		91
OPTICAL COVERAGE 30-150 m (km)	0	13	11	23	*	*	*	*	*	161	0

? unknown
— no data
*combined and presented as Maui Nui

Figure 30. MHI land and seafloor coverage with primary data coverage.

ISLAND CODE	KUR	MID	PHR	NEV	LIS	PIO	NHS	LAY	MAR	RAI	GAR	SRW	BBW	BBM	BBB	FFS	NEC	TWI	WNB	NIH
LAND AREA (km²)	<1	6	<1	0	2	0	0	4	0	0	0	0	0	0	0	<1	<1	0	0	<1
SEA FLOOR AREA 0-30 m (km²)	83	102	467	0	1004	306	0	488	1075	128	1269	250	3	<1	0	678	1028	0	0	<1
SEA FLOOR AREA 30-150 m (km²)	218	236	276	90	226	125	360	69	696	310	1136	124	142	135	23	244	473	63	320	573
BATHYMETRY 0-30 m (km²)	25	24	23	0	0	<1	0	0	73	0	<1	<1	2	<1	0	222	8	0	<1	<1
BATHYMETRY 30-150 m (km²)	218	180	251	34	125	54	20	58	588	0	126	40	142	135	23	214	312	13	165	163
OPTICAL COVERAGE 0-30 m (km)	32	43	63	0	57	0	0	14	40	1	4	0	<1	<1	0	106	8	0	0	0
OPTICAL COVERAGE 30-150 m (km)	21	13	20	0	8	0	0	<1	2	<1	<1	1	3	<1	<1	90	6	0	0	0

? unknown
— no data
*numbers refer to area from 0-150 m

Figure 31. NWHI land and seafloor coverage with primary data coverage.

2.6.2.2 Benthic Habitat

Juvenile and adult life stages of coral reef MUS and crustaceans including spiny and slipper lobsters and 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), while the type of bottom habitat varies by family for coral reef species (69 FR 8336, February 24, 2004). 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).

2.6.2.2.1 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae from CREP are found in the following tables. CREP uses the benthic towed-diver survey method to monitor changes in benthic composition. In this method, "a pair of scuba divers (one collecting fish data, the other collecting benthic data) is towed about 1 m above the reef roughly 60 m behind a small boat at a constant speed of about 1.5 kt. Each diver maneuvers a towboard platform, which is connected to the boat by a bridle and towline and outfitted with a communications telegraph and various survey equipment, including a downward-facing digital SLR camera (Canon EOS 50D, Canon Inc., Tokyo). The benthic towed diver records general habitat complexity and type (e.g., spur and groove, pavement), percent cover by functional-group (hard corals, stressed corals, soft corals, macroalgae, crustose coralline algae, sand, and rubble), and for macroinvertebrates (crown-of-thorns sea stars, sea cucumbers, free and boring urchins, and giant clams).

Towed-diver surveys are typically 50 minutes long and cover about 2-3 km of habitat. Each survey is divided into five-minute segments, with data recorded separately per segment to allow for later location of observations within the ~ 200-300 m length of each segment. Throughout each survey, latitude and longitude of the survey track are recorded on the small boat using a GPS; and after the survey, diver tracks are generated with the GPS data and a layback algorithm that accounts for position of the diver relative to the boat. (PIFSC Website, 2016).

Table 67. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys in the MHI.

Year	2005	2006	2008	2010	2016
Hawaii		18.38	17.11	22.1	25.65
Kauai	6.06	12.27	7.04	6.04	6.99
Kaula		6.9			
Lanai	30.48	26.61	22.42	23.34	30.42
Maui	18.99	20.33	12.06	14.62	11.91
Molokai	35.66	6.96	6.92	52.17	18.85
Niihau	5.03	2.39	2.29	2.26	3.44
Oahu	9.36	12.21	9.45	8.19	

Table 68. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys in the MHI.

Year	2005	2006	2008	2010	2016
Hawaii		5.46	1.01	1.05	0.29
Kauai	35.67	27.92	16.45	16.25	9.61
Kaula		5.94			
Lanai	7.38	13.18	17.13	11.14	2.69
Maui	17.84	16.24	12.04	2.13	12.12
Molokai	23.31	24.22	12.71	4.75	9.47
Niihau	41.30	14.57	2.58	2.22	0.03
Oahu	37.03	27.41	12.58	13.03	

Table 69. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys in the MHI.

Year	2005	2006	2008	2010	2016
Hawaii		14.82	16.09	6.94	5.97
Kauai	3.67	2.94	4.14	1.71	2.70
Kaula		7.40			
Lanai	2.42	1.31	3.72	2.82	0.03
Maui	4.37	4.83	6.82	4.31	1.22
Molokai	3.71	3.79	5.24	4.19	0.65
Niihau	10.87	6.68	8.05	1.88	0.28
Oahu	13.95	2.74	4.28	2.42	

Table 70. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys in the NWHI.

Year	2000	2001	2002	2003	2004	2006	2008	2010	2016
French Frigate	27.23	5.00	14.22	13.47	11.29	18.25	15.23	13.28	17.53
Gardner	3.00			2.50	1.65				
Kure	7.3		9.61	12.34	12.63	17.2	17.6	14.57	13.08
Laysan	9.96		9.76	4.00	7.33	6.96	8.43		
Lisianski	28.17		24.29	15.2	26.81	27.22	25.69	27.56	26.96
Maro	27.38	18.31	13.77	16.54	25.59	22.67	19.78		

Midway			5.58	3.06	1.24	3.91	2.66		
Necker	6.50			14.52		14.92			
Nihoa	3.89								
Pearl & Hermes	15.82		10.71	6.47	9.45	11.64	10.79	8.25	7.91
Raita		2.50							

Table 71. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys in the NWHI.

Year	2000	2001	2002	2003	2004	2006	2008	2010	2016
French Frigate	0.00	10.50	30.13	29.05	23.15	17.33	17.81	18.42	9.60
Gardner	0.00			73.63	26.94				
Kure	0.00		38.84	42.79	29.84	23.14	26.22	12.99	11.00
Laysan	0.00		26.90	47.03	30.63	28.66	25.70		
Lisianski	0.00		20.04	24.61	17.14	21.46	20.83	13.85	10.92
Maro	0.00	17.01	20.39	17.69	30.01	20.79	18.19		
Midway			42.28	44.90	24.86	11.02	19.93		
Necker	0.00			23.39		33.51			
Nihoa	0.00								
Pearl & Hermes	0.00		36.94	41.51	114.87	33.56	33.79	36.96	39.84
Raita		68.83							

Table 72. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys in the NWHI.

Year	2000	2001	2002	2003	2004	2006	2008	2010	2016
French Frigate	0.00	0.00	8.55	8.56	2.52	9.46	8.55	1.87	4.21
Gardner	0.00			9.13	1.50				
Kure	0.00		3.38	7.65	5.87	7.31	6.91	4.11	7.18
Laysan	0.00		3.95	11.17	5.11	10.21	7.93		
Lisianski	0.00		14.21	7.97	12.11	17.19	17.42	11.78	13.29
Maro	0.00	13.95	15.17	12.89	4.36	16.54	15.29		
Midway			7.58	3.69	7.17	5.80	5.62		
Necker	0.00			7.86		1.48			

Year	2000	2001	2002	2003	2004	2006	2008	2010	2016
Nihoa	0.00								
Pearl & Hermes	0.00		14.13	14.38	11.84	10.07	12.43	7.61	14.44
Raita		0.42							

2.6.2.3 Oceanography and Water Quality

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 Ecosystem and Climate Change section for information related to oceanography and water quality.

2.6.3 Report on Review of EFH Information

One EFH review was drafted this year; the review of the biological components of crustaceans EFH can be found in Appendix C.

2.6.4 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. In subsequent SAFE reports, each fishery section will include the description of EFH method, method used to assess the value of the habitat to the species, description of data sources used if there was analysis; and description of method for analysis.

2.6.4.1 Precious Corals

Essential Fish Habitat for precious corals was originally designated in Amendment 4 to the Precious Corals Fishery Management Plan (64 FR 19067, April 19, 1999), using the level of data found in the table.

Table 73. Level of EFH available for Hawaii precious corals MUS complex.

Species	Pelagic phase (larval stage)	Benthic phase	Source(s)
Pink Coral (*Corallium*)			
Pleurocorallium secundum	0	1	Figueroa & Baco, 2014

Species	Pelagic phase (larval stage)	Benthic phase	Source(s)
(prev. *Corallium secundum)*			HURL Database
C. regale	0	1	HURL Database
Hemicorallium laauense (prev. C. laauense)	0	1	HURL Database
Gold Coral			
Kulamanamana haumeaae (prev.	0	1	Sinniger, *et al.* (2013) HURL Database
Callogorgia gilberti	0	1	HURL Database
Narella spp.	0	1	HURL Database
Bamboo Coral			
Lepidisis olapa	0	1	HURL Database
Acanella spp.	0	1	HURL Database
Black Coral			
Antipathes griggi (prev. *Antipathes dichotoma)*	0	2	Opresko, 2009 HURL Database
A. grandis	0	1	HURL Database
Myriopathes ulex (prev. *A. ulex)*	0	1	Opresko, 2009 HURL Database

2.6.4.2 Bottomfish and Seamount Groundfish

Essential Fish Habitat for bottomfish and seamount groundfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, April 19, 1999).

Table 74. Level of EFH information available for Hawaii bottomfish and seamount groundfish management unit species complex.

Life History Stage	Eggs	Larvae	Juvenile	Adult
Bottomfish: (scientific/English common)				
Aphareus rutilans (red snapper/silvermouth)	0	0	0	2
Aprion virescens (gray snapper/jobfish)	0	0	1	2
Caranx ignoblis (giant trevally/jack)	0	0	1	2
C. lugubris (black trevally/jack)	0	0	0	2
Epinephelus faciatus (blacktip grouper)	0	0	0	1
E quernus (sea bass)	0	0	1	2
Etelis carbunculus (red snapper)	0	0	1	2
E. coruscans (red snapper)	0	0	1	2
Lethrinus amboinensis (ambon emperor)	0	0	0	1
L. rubrioperculatus (redgill emperor)	0	0	0	1
Lutjanus kasmira (blueline snapper)	0	0	1	1
Pristipomoides auricilla (yellowtail snapper)	0	0	0	2
P. filamentosus (pink snapper)	0	0	1	2

Life History Stage	Eggs	Larvae	Juvenile	Adult
P. flavipinnis (yelloweye snapper)	0	0	0	2
P. seiboldi (pink snapper)	0	0	1	2
P. zonatus (snapper)	0	0	0	2
Pseudocaranx dentex (thicklip trevally)	0	0	1	2
Seriola dumerili (amberjack)	0	0	0	2
Variola louti (lunartail grouper)	0	0	0	2
Seamount Groundfish:				
Beryx splendens (alfonsin)	0	1	2	2
Hyperoglyphe japonica (ratfish/butterfish)	0	0	0	1
Pseudopentaceros richardsoni (armorhead)	0	1	1	3

2.6.4.3 Crustaceans

Essential Fish Habitat for crustaceans MUS 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 75. Level of EFH information available for Hawaii crustacean management unit species complex.

Life History Stage	Eggs	Larvae	Juvenile	Adult
Crustaceans: (English common\scientific)				
Spiny lobster (*Panulirus marginatus*)	2	1	1-2	2-3
Spiny lobster (*Panulirus pencillatus*)	1	1	1	2
Common slipper lobster (*Scyllarides squammosus*)	2	1	1	2-3
Ridgeback slipper lobster (*Scyllarides haanii*)	2	0	1	2-3
Chinese slipper lobster (*Parribacus antarcticus*)	2	0	1	2-3
Kona crab (*Ranina ranina*)	1	0	1	1-2

2.6.4.4 Coral Reef

Essential Fish Habitat for coral reef ecosystem species was originally designated in the Coral Reef Ecosystem FMP (69 FR 8336, February 24, 2004). An EFH review of CREMUS will not be undertaken until the Council completes its process of re-designating certain CREMUS into the ecosystem component classification. Ecosystem component species do not require EFH designations, as they are not a managed species.

2.6.5 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:

2.6.5.1 All FMP Fisheries

- Distribution of early life history stages (eggs and larvae) of management unit species 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.

2.6.5.2 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.

2.6.5.3 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.

2.6.5.4 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 1000 meters in depth.
- Continuous backscatter or LIDAR data in depths shallower than 60 m.

2.6.6 References

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2.7 MARINE PLANNING

2.7.1 Introduction

Marine planning is a science-based 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. The Council's efforts to formalize incorporation of marine planning in its actions began in response to Executive Order 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes. Executive Order 13158, Marine Protected Areas (MPAs), proposes that agencies strengthen the management, protection, and conservation of existing 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, Hawai`i, the Council approved the following objective for the FEPs: 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 Fishing Restricted Areas, military installations, NWHI restrictions, and Marine Life Conservation Districts.
- 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.

In order to monitor implementation of this objective, this annual report includes the Council's spatially-based fishing restrictions or marine managed areas (MMAs), the goals associated with those, and the most recent evaluation. Council research needs are identified and prioritized through the 5 Year Research Priorities and other processes, and are not tracked in this report.

In order 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 or 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 FEP's EFH cumulative impacts section. These are redundant efforts; therefore, this report can provide material or suggest resources to meet both mandates.

2.7.2 Response to Previous Council Recommendations

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

2.7.3 Marine Managed Areas Established Under FEPs

Council-established marine managed areas (MMAs) were compiled in Table 76 from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. Geodesic areas were calculated in square kilometers in ArcGIS 10.2. Regulated fishing areas, including the Papahānaumokuākea Marine National Monument, are shown in Figure 32.

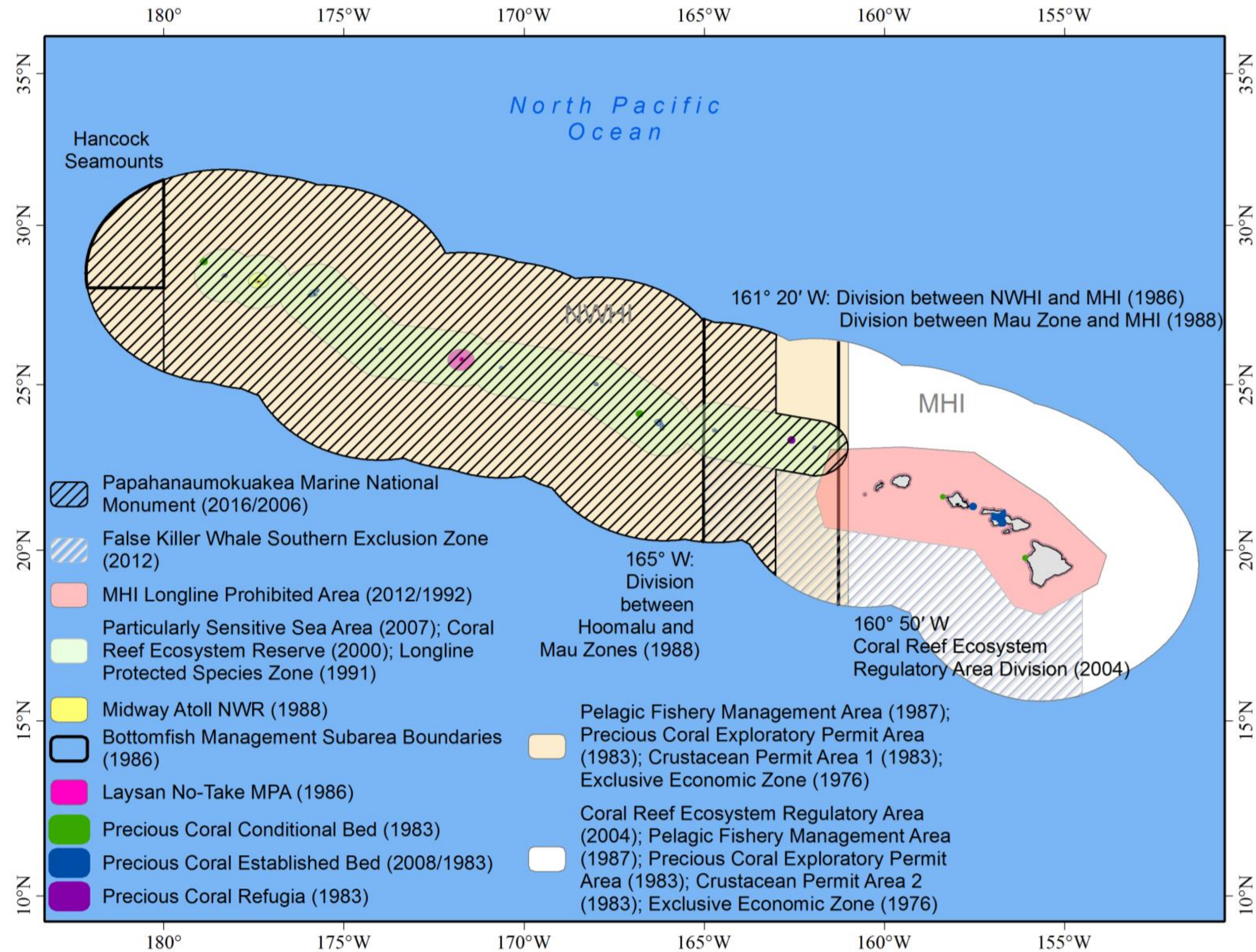

Figure 32. Regulated fishing areas of the Main Hawaiian Islands.

Table 76. MMAs established under FEP from 50 CFR § 665.

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km²)	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 Pelagic FMP Am. 3	351,514.00	Longline fishing prohibited	Prevent longline interaction with monk seals	1991	-
MHI Longline Prohibited Area	Pelagic (Hawaii)	MHI	665.806(a)(2) 57 FR 7661 Pelagic FMP Am. 5	248,682.38	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 Moratorium: 51 FR 27413 Bottomfish FMP	60,826.75	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								
Keahole Point	Hawaii Archipelago	Hawaii Island	665.261(2)(i) 73 FR 47098 Precious Corals FMP Am. 7	2.7	Fishing by permit only	Manage harvest	2008	-
Kaena Point	Hawaii Archipelago	Oahu	665.261(2)(ii) 73 FR 47098 Precious Corals FMP Am. 7	2.7	Fishing by permit only	Manage harvest	2008	-
Makapuu	Hawaii Archipelago	Oahu	665.261(1)(i) 73 FR 47098 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 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 Precious Corals FMP Am. 7	43.15	Fishing by permit only	Manage harvest	2008	-
Westpac Bed	Hawaii Archipelago	NWHI	665.261(3) 73 FR 47098 Precious Corals FMP Am. 7	43.15	Fishing prohibited	Manage harvest	2008	-
Auau Channel	Hawaii Archipelago	Maui Nui	665.261(1)(ii) 73 FR 47098 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	-

2.7.4 Fishing Activities and Facilities

2.7.4.1 Aquaculture Facilities

Hawaiʻi has one permitted offshore aquaculture facility. The information in Table 77 was transferred from the Joint NMFS and U.S. Army Corps of Engineers EFH Assessment for the Proposed Issuance of a Permit to Authorize the Use of a Net Pen and Feed Barge Moored in Federal Waters West of the Island of Hawaii to Fish for a Coral Reef Ecosystem Management Unit Species, *Seriola rivoliana* (RIN 0648-XD961), unless otherwise noted.

Table 77. Aquaculture facilities.

Name	Size	Location	Species	Stage
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 Hawaiʻi Island 19 deg 33 min N 156 deg 04 min W. mooring scope is 10,400 foot radius.	*Seriola rivoliana*	Permit authorizes culture and harvest of 30,000 kampachi. In March 2017 the Kampachi Farms permit was transferred to Forever Oceans Corporation. Because of the delay in beginning culture activities the permit was extended through March 31, 2019. No gear is in the water at this time (pers. comm. David Nichols, March 8, 2018).

2.7.5 Non-Fishing Activities and Facilities

The following section includes activities or facilities associated with known uses and predicted future uses. The Plan Team will add to 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 in this report. 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.

2.7.5.1 Alternative Energy Facilities

Hawaiʻi has three proposed wind energy facilities in Federal waters and several existing alternative energy facilities. The information in

Table **78** is from various sources.

Table 78. Alternative Energy Facilities and Development.

Name	Type	Location	Impact to Fisheries	Stage of Development	Source

Name	Type	Location	Impact to Fisheries	Stage of Development	Source
AWH O'ahu Northwest Project	408 MW Wind	12 miles W of Ka'ena Pt, O'ahu	Hazard to navigation; benthic impacts from cables	BOEM Area Identification and EA	BOEM Hawai`i
AWH O'ahu South Project	408 MW Wind	17 miles S of Waikiki, O'ahu	Hazard to navigation; benthic impacts from cables; close to Penguin Bank	BOEM Area Identification and EA	BOEM Hawai`i
Progression South Coast of Oahu Project	400 MW Wind	SSE of Barber's Pt and SW of Waikiki, O'ahu	Hazard to navigation; in popular trolling area; benthic impacts from cables	BOEM Area Identification and EA	Progression Energy BOEM Lease Application, BOEM Hawai`i
Statoil Wind US, LLC	-	-	-	BOEM Area Identification and EA	BOEM Hawaii
Natural Energy Laboratory of Hawai`i	120 kW OTEC Test Site/ 1 MW Test Site	West Hawai`i	Intake	120 kW operational; DEA for 1 MW Test Site using existing infrastructure submitted July 2012 HEPA Exemption List memo Dec. 27, 2016	http://nelha.Hawai`i.gov/energy-portfolio/ Final Environmental Assessment, NELHA, July 2012
Honolulu Sea Water Air Conditioning	SWAC	4 miles S of Kaka'ako, O'ahu	Benthic impacts; intake	USACE Record of Decision (ROD) signed	http://honoluluswac.com/pressroom.html
Marine Corps Base Hawai`i Wave Energy Test Site	Shallow- and Deep-Water Wave Energy	1, 2 and 2.5 km N of Mokapu, O'ahu	Hazard to navigation	Shallow and Deep-water wave energy units are operational	Final Environmental Assessment, NAVFACPAC, January 2014 http://www.eenews.net/stories/1060046254

2.7.5.2 Military Training and Testing Activities and Impacts

The Department of Defense major planning activities in the region are summarized below. Maps of the Hawaii-Southern California Range Complex from the Hawaii Range Complex FEIS are included in the maps section.

Action	Description	Phase	Impacts
Hawaii-Southern California Training and Testing	Increase naval testing and training activities	DEIS published October 13, 2017. Comment period closed Dec. 12, 2017. Staff attended a public hearing.	EFH consultation has not been initiated. Likely access and habitat impacts similar to previous analysis.

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 at the Pacific Missile Range Facility at Kauai, Hawaii	Comment period closed Feb. 6, 2017 on NMFS authorization to take marine mammals incidental to conducting munitions testing for their Long Range Strike Weapons Systems Evaluation Program (LRS WSEP) over the course of five years, from September 1, 2017 through August 31, 2022 (82 FR 1702).	Access – closures during training

2.7.6 Pacific Islands Regional Planning Body Report

The Council is a member of the Pacific Islands RPB and as such, the interests of the Council will be incorporated into the CMS plan. It is through the Council member that the Council may submit recommendations to the Pacific Islands RPB.

The Pacific Islands RPB met in Honolulu from February 14-15, 2018. The RPB's American Samoa Ocean Planning Team has completed its draft Regional Ocean Plan, on which the RPB provided comments and endorsement. CNMI and Guam Ocean Planning Teams have held their kick-off meetings. The RPB, by consensus, adopted the following goals for 2018: finalize the American Samoa Ocean Plan; continue planning in Guam and CNMI including conducting coastal and marine spatial planning training; transfer data portal prototype to permanent site and identify data gaps; and increase funding.

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3 DATA INTEGRATION

3.1 INTRODUCTION

3.1.1 Potential Indicators for Insular Fisheries

The purpose of this section ("Chapter 3") of the 2017 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 (WPR). "Fishery ecosystem relationships" are those associations between various fishery-dependent data measures (e.g. catch, effort, or catch-per-unit-effort), and other environmental attributes (e.g. precipitation, sea surface temperature, primary productivity) 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 what factors may be useful going forward.

To support the development of Chapter 3 of the annual SAFE report, staff from the Council, National Marine Fisheries Service (NMFS), Pacific Islands Fisheries Science Center (PIFSC), Pacific Islands Regional Offices (PIRO), and Triton Aquatics (consultants), held a SAFE Report Data Integration Workshop (hereafter, "the Workshop") convened on November 30, 2016 to identify potential fishery ecosystem relationships relevant to local policy in the WPR and determine appropriate methods to analyze them. Participants are listed in Table 79.

Table 79. Participants of the Data Integration Workshop held in late 2016.

Name	Affiliation	Name	Affiliation
Keith Bigelow	PIFSC	Kevin Kelley	Consultant/PIRO
Chris Boggs	PIFSC	Eric Kingma	Council
Rusty Brainard	PIFSC	Don Kobayashi	PIFSC
Paul Dalzell	Council	Tom Oliver	PIFSC
Joshua DeMello	Council	Michael Parke	PIFSC
Stefanie Dukes	PIFSC	Frank Parrish	PIFSC
Sarah Ellgen	PIRO	Marlowe Sabater	Council
Jamison Gove	PIFSC	Sylvia Spalding	Council
Justin Hospital	PIFSC	Rebecca Walker	Council
Asuka Ishizaki	Council	Mariska Weijerman	PIFSC

Ariel Jacobs	PIRO	Ivor Williams	PIFSC

Following background presentations and discussions regarding ecosystem-based fishery management (EBFM) and previous attempts at data integration, participants were segregated into two smaller working groups to brainstorm island and pelagic fishery and environmental/ecological relationships that may be of use in this section. Several guided questions were provided for every combination of variables:

- What can we reasonably expect to learn from or monitor with the results?
- How does it inform Council decision-making, consistent with the purposes of the FEP?
- Is it part of an ongoing research initiative?

The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships (Table 80) to examine across bottomfish, coral reef, and crustacean fisheries based on data reliability, suitability of methodology, repeatability on an annual basis, and how well analyses could potentially inform management decisions.

Table 80. List of prioritized potential fishery ecosystem relationships in insular areas of U.S. Western Pacific regions generated by the archipelagic fisheries group at the Data Integration Workshop.

Relationships	FEP	Score	Rank
Bottomfish catch/effort/CPUE/species composition and benthos/substrate (i.e. depth, structure)	All	22	3
Bottomfish catch/effort/ CPUE /species composition and Pacific Decadal Oscillation	All	20	3
Coral reef fish/fishery/biomass and temperature-derived variable	All	20	3
Akule/opelu and precipitation (MHI and Guam)	HI	20	3
Bottomfish catchability and wind speed	All	19	3
Coral reef fish/fishery/biomass and chlorophyll-*a* (with phase lag)	All	19	3
Bottomfish Catch /CPUE and lunar cycle/moon phase	All	19	3
Bottomfish catch/effort/ CPUE /species composition and sea-level height (eddy feature)	All	18	2
Coral reef fish/fishery/biomass and Pacific Decadal Oscillation	All	18	2
Green/red spiny lobster catch/CPUE and vertical relief	HI	18	2
Green/red spiny lobster catch/CPUE and Pacific Decadal Oscillation	HI	18	2
Bottomfish catchability and fishing conditions (i.e. surface, subsurface current, speed, and direction)	All	17	2

Coral reef fish/fishery/biomass and moon phase	All	17	2
Coral reef fish/fishery/biomass and Oceanic Niño Index	All	17	2
Coral reef fish/fishery/biomass and sea-level height	All	17	2
Coral reef fish/fishery/biomass and pH	All	17	2
Bottomfish catch/effort/ CPUE /species composition and temperature-derived variable (e.g. temperature at depth)	All	16	2
Bottomfish catch/effort/ CPUE /species composition and chlorophyll-*a* (with phase lag)	All	16	2
Bottomfish catch/effort/ CPUE /species composition and precipitation	All	16	2
Coral reef fish/fishery/biomass and structural complexity /benthic habitat	All	16	2
Bottomfish catch/effort/ CPUE /species composition and dissolved oxygen	All	15	2
Coral reef fish/fishery/biomass and precipitation	All	14	2
Bottomfish catch/effort/ CPUE /species composition and pH	All	13	2
Bottomfish catch/effort/ CPUE /species composition and predator abundance	All	12	2
Coral reef fish/fishery/biomass and salinity	All	12	2
Coral reef fish/fishery/biomass and dissolved oxygen	All	12	2
Bottomfish catch/effort/ CPUE /species composition and salinity	All	10	1

Before delving into the content itself, the results are prefaced by Plan Team recommendations for ongoing development and improvement of the existing data integration chapter. Then, the chapter will include brief descriptions of past work on fishery ecosystem relationship assessment in coral reefs of the U.S. Western Pacific, followed by initial evaluations of relationships previously recommended for analysis by participants of the Workshop using current data streams in Hawaii. The evaluations completed were exploratory in nature, and were used as the first step of analyses to know which comparisons may hold more utility going forward. Those relationships deemed potentially relevant were emphasized and recommended for further analysis. 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 2.5.3, and as the strength of certain fishery ecosystem relationships relevant to advancing ecosystem-based fishery management are determined.

3.1.2 2018 Plan Team Recommendations for Section Development

At the most recent FEP Plan Team Meeting held on April 30th and May 1st, 2018, participants were presented preliminary data integration results shown here, and 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 be implemented in the coming year to ensure that more refined analyses comprise the data integration section. FEP 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 (e.g. purse seine harvest of *Selar crumenophthalmus* in the MHI).
- 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.
- Spatial specificity and precision should be increased for analyses of environmental variables in relation to areas commonly fished.

At its 172nd Council meeting, the WPRFMC provided no formal recommendations. However, it was suggested by individual Council members that, in addition to implementing additional data streams when time series of sufficient length become available (e.g. bio-sampling data), that the results should be standardized in such that they can be presented as estimated potential percent change in the fishery in response to measured environmental variability.

At its 128th meeting, the Science and Statistical Committee (SSC) was also presented the preliminary data integration results shown here. Going forward, the SSC suggested the use of multivariate assessment in the form of Structural Equation Models to determine difference in parameters between years, but there existed disagreement as to whether these analyses should be used only as precedence for more thorough univariate assessments. Additionally, it was suggested that examining the potential fishery ecosystem relationships from an energetics perspective may emphasize changes in the fishery associated with ecological change. However, it was noted that such relationships between fishery and environmental parameters, if they exist, may already be (or should already be) represented in prevailing stock assessments.

Incorporating such recommendations into the 2018 version of 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 Past Work

Richards *et al.* (2012) performed a study on a range 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 deep water 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/or ecosystem change on coral reefs fish stocks of American Samoa using climate and oceanic indicators (see Section 2.5.3). 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 was also noted that larger natural disturbances in recent decades, such as cyclones and tsunamis, negatively impacted reef fish assemblages and lowed reef fishery CPUE in American Samoa (Ochavillo *et al*., 2012).

On a larger spatial scale, an analysis of various drivers on coral reef fish populations across 37 U.S.-affiliated islands in the Central and Western Pacific was performed by Williams *et al.* (2015), and evaluated relationships between fish biomass in these reefs with human and environmental factors. Again, reef fish assemblages were negatively associated with increasing human population density (even at relatively low levels) across the WRP, but were positively associated with elevated levels of ocean productivity across islands. The authors warned, however, that the ability of reefs surrounding uninhabited islands to maintain fish populations varies, and that high biomass observed in remote areas (e.g. the NWHI) may not necessarily be reflective of baselines or recovery response levels for all reef systems.

A common method of EBFM used in coral reef ecosystems is the implementation of biological reference points, statistical indicators of potential overfishing used to help determine how a fishery is performing relative to these points at a given time (McClanahan *et al*., 2007). Hawhee (2007) adapted this idea, generating biological reference points in the form of CPUE-based proxies to be used as indicators for reef fish stocks in the WPR. However, the devised method was determined to be inappropriate for application in management of reef stocks in the U.S. Western Pacific due to the lack of a historical CPUE to use as a baseline for the reference points and their limit thresholds (Remington and Field, 2016).

3.2 PRECIPITATION

Participants of the Workshop determined that the potential fishery ecosystem relationships between precipitation levels and akule and opelu (bigeye scad and mackerel scad, *Selar crumenophthalmus* and *Decapterus macarellus,* respectively) were among the highest priority of those involving coral reef fisheries in the MHI. It has been suggested that the recruitment of small tropical pelagic fish is related to annual rainfall and subsequent runoff enrichment (Longhurst and Pauly, 1987). The direct freshwater and nutrient input to reefs associated with increased precipitation can alter the physiochemical composition of the water, and it has been shown that reef assemblages are positively associated with this sort of increased ocean productivity (Williams *et al.*, 2015). Weng and Sibert (2000) explicitly suggested a link between precipitation levels and the carrying capacity for akule in the MHI with a phase lag of two years. Data for precipitation in the MHI was gathered from local databases maintained by the National Weather Service (NWS-HI). Based on direction from SSC members, future analyses involving precipitation and fishery parameters will look to include time series from the Hawaii State Rainfall Atlas or station data from the NWS.

3.2.1 Trends in Precipitation

Figure 33and Figure 34show that total annual precipitation in both the Honolulu and Hilo areas have had non-significant, interannually-variable trends over the last seven decades (e.g. for Honolulu, R^2=0.14; CV=46.0; Figure 33). Honolulu precipitation was the focus for many of the comparisons, though Hilo rainfall data was more closely considered when subsequently incorporating phase lag, etc.

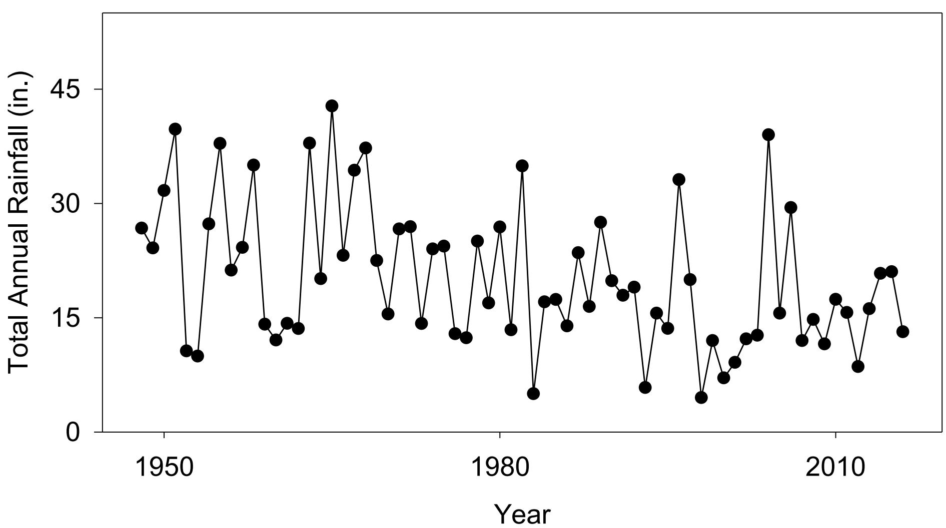

Figure 33. Annual rainfall (in.) for the Honolulu area of Oahu, HI from 1948-2016.

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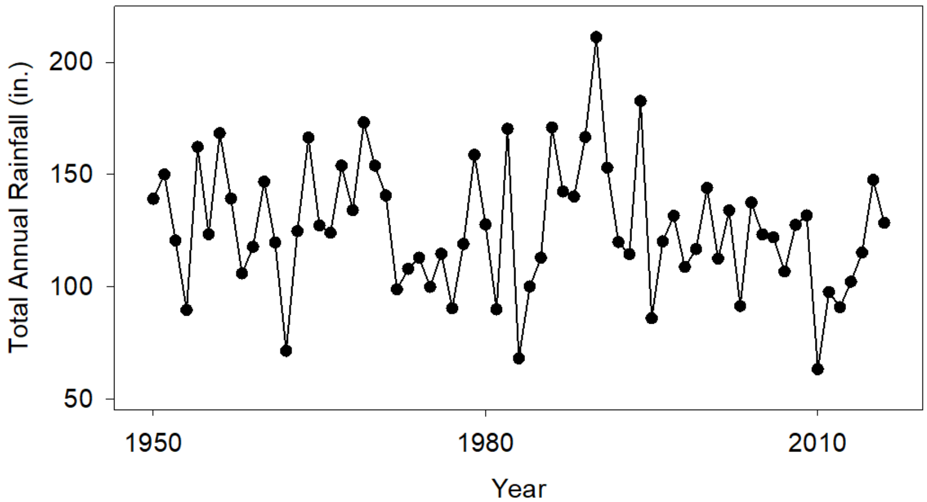

Figure 34. Annual rainfall (in.) for the Hilo area of the Big Island, HI from 1950-2016.

3.2.2 Relationship with Hawaiian scads

3.2.2.1 Akule

Total annual akule landings in the MHI commercial coral reef fishery have been showing a slight increase over the last several decades with a maximum catch of over 1.2 million lbs. in the early 2000s, though the trend is not statistically significant considering the entirety of the available time series (R^2=0.08; CV=50.5; Figure 35). The number of annual fishing trips for akule, conversely, has been observably declining since 1948 with a more observable (non-significant) trend apart from some increased effort in the late 20th century (R^2=0.15; Figure 35). The slight increase in Hawaiian akule landings combined with decreasing effort over the course of the time series has led to an increase in akule CPUE in the MHI over time, though this trend was also not statistically significant (R^2=0.17; Figure 35).

In comparing the time series of commercial CPUE for akule to total annual rainfall in the MHI, there are some segments of the time series that visually appeared to co-vary, especially in the mid-1980s and late-2000s (Figure 36). Analyzing further, the correlation between akule CPUE in the MHI and these two rainfall parameters showed almost no association considering all available data (R^2=0.01 and R^2=0.00, respectively; Figure 37). It has been suggested that evaluating the entirety of the time series may obfuscate any potential relationship between akule and interannual precipitation because of major shifts in fishery dynamics over the decades (Miyasaka, A., personal communication).

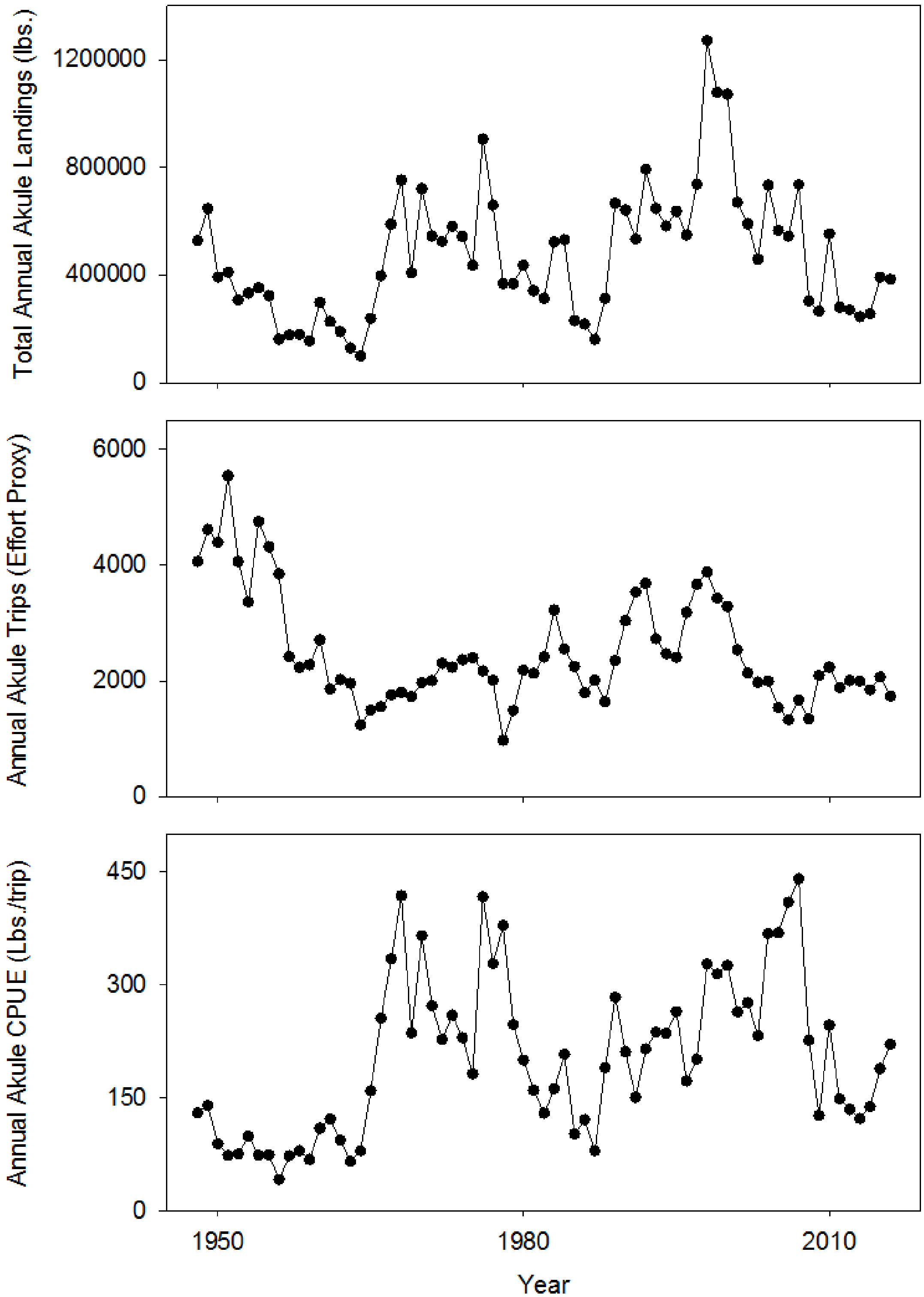

Figure 35. **Time series of landings (lbs.; top), effort (number of fishing trips; middle), and CPUE (lbs./trip; bottom) for akule harvested in the MHI commercial coral reef fishery from 1948-2016.**

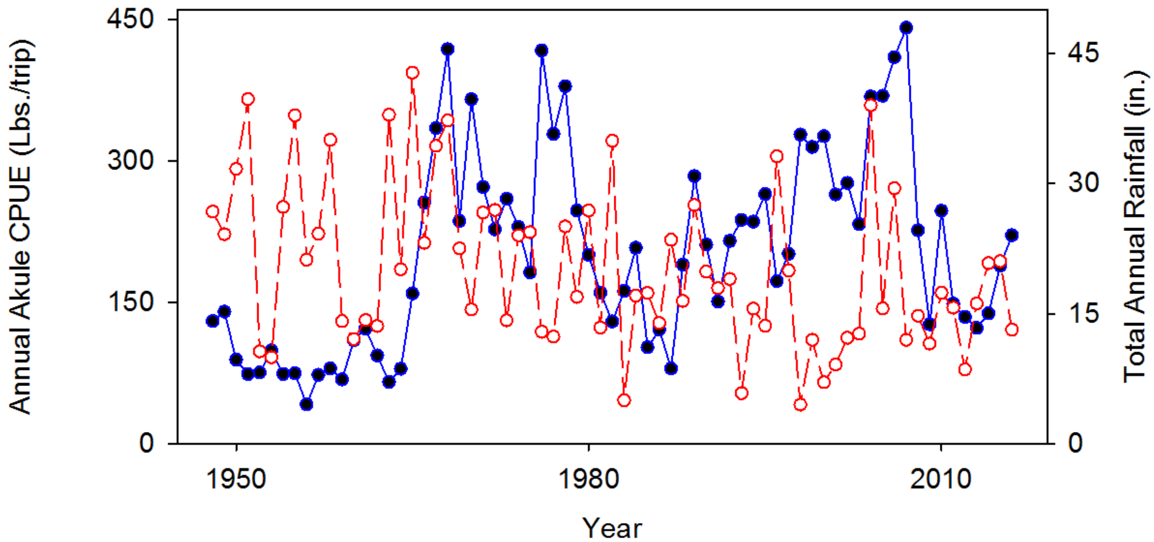

Figure 36. Comparison of time series of annual CPUE (lbs./trip) for akule in the MHI commercial coral reef fishery and total annual rainfall (in.) in the Honolulu area from 1948-2016.

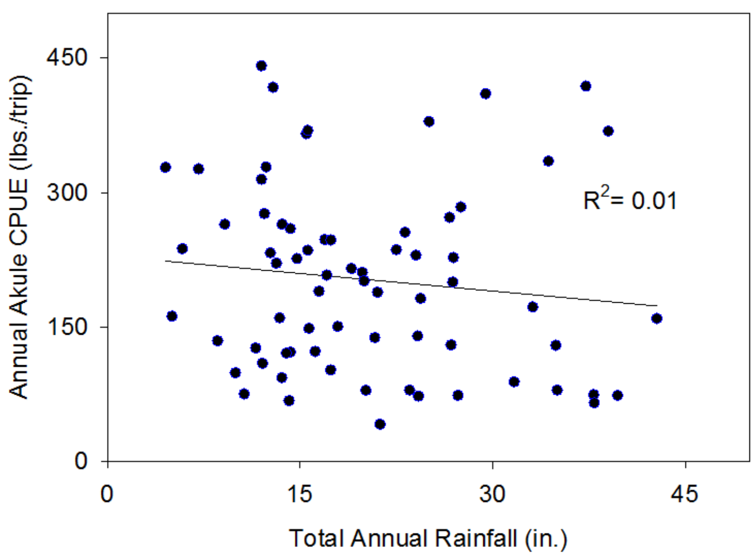

Figure 37. Linear regression between MHI commercial coral reef akule CPUE and annual rainfall (in.) from 1948-2016.

3.2.2.2 Opelu

Opelu catch, effort, and CPUE over the past seven decades in the commercial coral reef fishery of the MHI showed no notable trends despite having slightly less variability than observed for akule (all $R^2 < 0.01$; CV = 48.0; Figure 38). The opelu data showed similar levels of effort in the fishery over time as the akule records, however akule were often landed in larger amounts and thus had a relatively higher CPUE (Figure 35 and Figure 38).

Comparing time series of rainfall in the MHI to CPUE data for opelu harvested commercially over the same period was much more problematic due to outliers, though the rest of the time series has a similar scope of variability as the CPUE time series (CV = 46.0; Figure 39).These outliers apparent in the opelu fishery data were initially thought to contribute to the lack of association due to anomalously high catch (e.g. 1952) and low effort (e.g. 1978); the removal of these outliers, however, did not improve the identification of any relationship. Similar to the akule evaluations, opelu CPUE data showed no general relationship with total annual rainfall ($R^2 = 0.00$; Figure 40).

Several other comparisons were performed to determine if any relationship existed between rainfall rates and akule/opelu CPUE across different gear types or more recent portions of the available CPUE time series in the MHI (Figure 35). Considering fishery data by gear, neither akule nor opelu CPUE data from several prominent gear types showed any significant association with total annual rainfall records ($R^2 > 0.075$; Table 81). Additionally, there was no notable difference in the correlation coefficients between akule and opelu CPUE and rainfall records from the MHI across all gear types considering only standardized data after 1966 ($R^2 =$ 0.02 and 0.00, respectively).

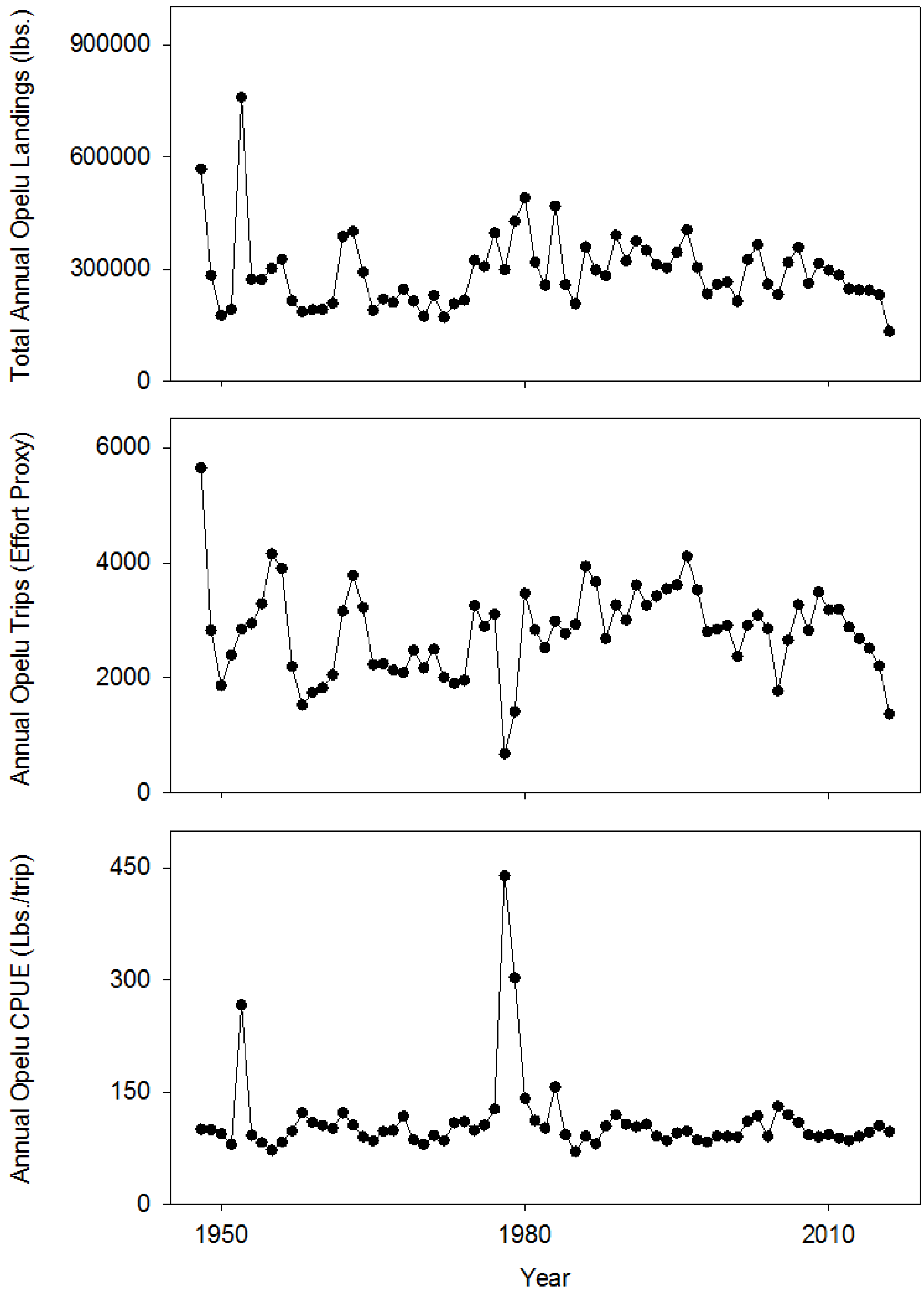

Figure 38. Time series of landings (lbs.; top), effort (number of fishing trips; middle), and CPUE (lbs./trip; bottom) for opelu harvested in the MHI commercial coral reef fishery from 1948-2016.

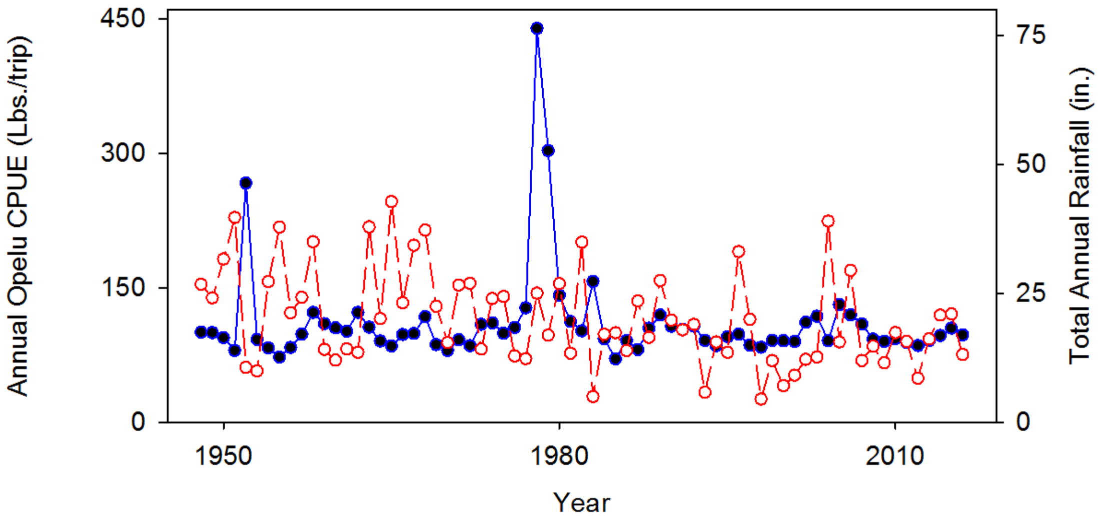

Figure 39. Comparison of time series of annual CPUE (lbs./trip) for opelu in the MHI commercial coral reef fishery and total annual rainfall (in.) in Honolulu from 1948-2016.

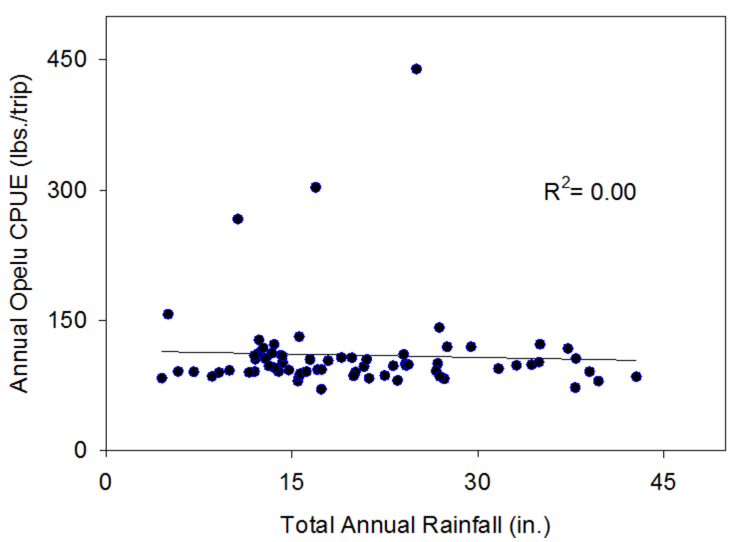

Figure 40. Linear regression between CPUE in the MHI coral reef commercial opelu fishery and the total annual rainfall (in.) from 1948-2016.

Table 81. Coefficients of determination (R^2) for comparisons of time series of rainfall and akule/opelu CPUE by gear in the MHI commercial reef fishery from 1948-2016.

	Akule				Opelu		
	Inshore Handline	Gill Net	Akule Net	Bottom Handline	Inshore Handline	Lift Net	Bottom Handline
Total Annual Rainfall (in.)	0.02	0.07	0.02	0.02	0.00	0.01	0.06

3.2.3 Incorporating Phase Lag(s)

Correlations were performed on time series of catch, effort, and CPUE from akule and opelu caught in the MHI commercial coral reef fishery with records of rainfall from the Honolulu and Hilo areas of the state with a phase lag of one to three years. Correlations with the addition of one year of phase lag did not produce any statistically significant *r*-values for any of the comparisons performed involving CPUE for either species (Table 82 and Table 83). The one fishery parameter that showed a significant relationship with Honolulu rainfall was akule effort from 1966-2016 such that increased rain in each year was associated with decreased effort one year later (r = -0.30). In addition to being well below the $|r|$ = 0.5 level suggested by Weng *et al.* (2000) to indicate a causal link, albeit with a slightly longer time series, it would not necessarily follow that effort in a fishery would be directly impacted by environmental factors a year after the data was recorded.

Correlations with two years of phase lag produced relatively more statistically significant correlation coefficients with representation in each of the three different time series lengths under assessment, though all significant *r*-values that were identified showed a negative relationship between rainfall and akule catch or effort (e.g. r= -0.27 through -0.46; Table 82). There were significant correlations for each time series between akule catch and rainfall, however these results indicated a negative relationship such that increased rainfall coincided with decreased catch two years later and vice versa (Table 82). In addition to being below Weng *et al.*'s causality threshold, correlations involving CPUE with the same amount of phase lag were weak.

Lastly for potential fishery ecosystems relationships with rainfall represented by comparisons of fishery parameters for akule and opelu with Honolulu precipitation records, correlations with three years of phase lag generated a small amount of statistically significant *r*-values, but only for catch and effort for akule (Table 82). For both the 1948 and 1966 time series, there was a negative statistically significant correlation coefficient calculated for akule catch (r = -0.27 and -0.34, respectively). The strongest of all observed relationships in this portion of these analysis was between akule CPUE and rainfall with no incorporated lag, but only when comparing the time series starting from 1980 (r = 0.47; Table 82).

Table 82. Correlation Coefficients (*r*) generated from MHI commercial fishery harvest parameters for akule/opelu with rainfall records for Honolulu over three periods.

Location of Rainfall	Honolulu area, Oahu											
Year Range	1948-2016				1966-2016				1980-2016			
Phase Lag (t = years)	No lag	t+1	t+2	t+3	No lag	t+1	t+2	t+3	No lag	t+1	t+2	t+3
AKULE												
Catch	-0.11	-0.23	**-0.27**	**-0.27**	0.00	-0.23	**-0.32**	**-0.34**	-0.01	-0.21	**-0.32**	-0.29
Effort	0.08	0.07	-0.09	-0.09	-0.11	**-0.30**	**-0.46**	**-0.42**	0.04	-0.18	**-0.37**	**-0.36**
CPUE	-0.05	-0.12	-0.14	-0.15	0.16	0.05	-0.04	-0.11	0.08	-0.02	-0.07	-0.05
OPELU												
Catch	0.05	-0.16	-0.06	0.11	-0.06	-0.17	-0.03	-0.08	0.19	0.11	0.22	0.06
Effort	-0.16	-0.05	-0.04	0.11	-0.24	-0.22	-0.20	-0.10	-0.14	0.06	-0.09	-0.06
CPUE	0.09	-0.05	-0.02	0.04	0.03	0.06	0.08	0.04	**0.47**	0.03	0.16	0.14

Correlations performed on fishery parameters from akule and opelu caught in the MHI commercial reef fishery with records of rainfall from Hilo showed no statistically significant values for opelu across time series and ranges of phase lag implemented (Table 83). Additionally, there was only one statistically significant *r*-value calculated for akule; species CPUE from 1980-2016 and a phase lag of +3 years produced a correlation coefficient of $r = -0.43$ when compared with the Hilo rainfall time series.

Table 83. Correlation Coefficients (*r*) generated from MHI commercial fishery harvest parameters for akule/opelu with rainfall records for Honolulu over three periods.

Location of Rainfall	Hilo area, Big Island											
Year Range	1948-2016				1966-2016				1980-2016			
Phase Lag (t = years)	No lag	t+1	t+2	t+3	No lag	t+1	t+2	t+3	No lag	t+1	t+2	t+3
AKULE												
Catch	-0.04	-0.03	0.02	-0.19	-0.02	-0.02	0.03	-0.24	0.00	0.02	0.05	-0.29
Effort	0.09	0.00	0.03	0.03	-0.03	-0.14	-0.01	-0.02	0.06	-0.05	0.08	0.07
CPUE	-0.06	0.02	-0.01	-0.21	0.00	0.10	0.03	-0.27	-0.05	0.03	-0.04	**-0.43**
OPELU												
Catch	-0.09	-0.09	0.20	0.05	-0.06	-0.06	0.06	0.03	-0.02	-0.04	0.08	0.00
Effort	0.01	0.02	0.13	0.11	-0.02	-0.12	0.07	0.08	0.09	-0.02	0.13	0.06
CPUE	-0.04	0.02	0.03	-0.07	0.01	0.13	-0.05	-0.06	-0.10	-0.01	-0.06	-0.07

In summary, no fishery ecosystem relationship could be established between akule or opelu catch, effort, or CPUE and precipitation levels in the MHI from 1948 till present with no incorporation of phase lag, and no standardized index/threshold characteristic of the association between the parameters could be identified representative of an immediate population response. Exploring these same potential associations with the influence of phase lag, a strong relationship between CPUE and rainfall could not be identified within three years of lag. Though correlation coefficients were statistically significant in some instances, it was not clear if the values were reflecting the variability in the fishery parameters explained by environmental variation.

Conversely, the lack of a strong relationship discovered in these analyses does not prohibit the potential influence that precipitation levels may have in the populations of akule and opelu in the MHI, and it is more likely a combination of environmental drivers that are responsible for observed patterns in fishery parameters over the last several decades. While correlations between the two variables were also evaluated on a monthly basis, the results have yet to be finalized/

3.3 SEA SURFACE TEMPERATURE

3.3.1 Trends in Sea Surface Temperature

Sea surface temperature (SST) is a commonly used diagnostic tool in monitoring climate change and its affects both regionally and globally, as it is representative of changes in ocean temperatures over time that can affect coastal fisheries (see Section 2.5.3.3). The potential influence of temperature-derived variables in fishery ecosystem relationships for U.S. Western Pacific coral reef stocks was deemed to be among the highest priority by the participants of the Workshop. Data for SST was gathered from the NOAA's AVHRR Pathfinder v5.0 through the OceanWatch program in the Central Pacific (NOAA/NESDIS/OceanWatch).

Time series of annual SST around the MHI from 1985-2016 are shown in Figure I. Temperature time series displayed relatively low variability over time (CV = 1.51). There seemed to be a slight increase in temperature over time, with some of the highest average annual temperatures recorded in the past three years. The average SST over the course of evaluated data was 25.8°C. The highest recorded SST over the course of the time series was 26.6°C in the year 2004, whereas the lowest occurred just six years prior in 1998 (25.1°C; Figure 41).

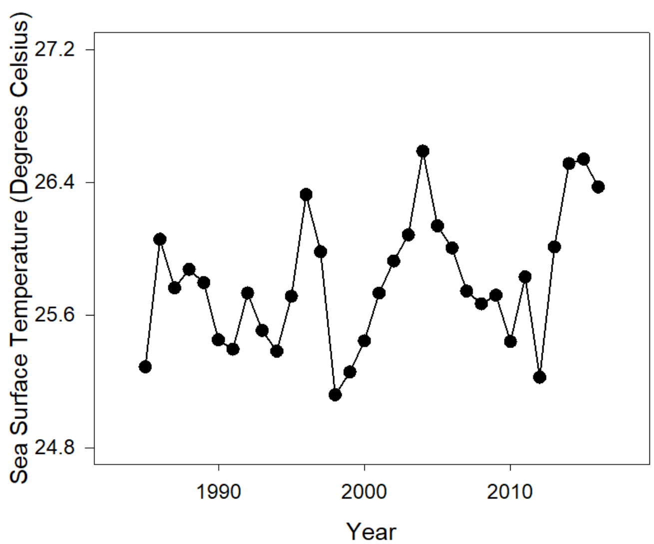

Figure 41. Time series of average annual SST (°C) in the MHI from 1985-2016 (CV = 1.51).

3.3.2 Relationship with Entire Commercial Reef Fishery

Plots depicting comparisons of time series of SST and catch, effort, and CPUE for the commercial coral reef fishery in the MHI from 1985-2016 are shown in Figure 42. Though landings from the past decade have generally been recorded in similar amounts to those from the mid-1980s, 2016 had the lowest recorded amount of commercial coral reef fish landings (< 85,000 lbs.) and catch has since been decreasing from the observed maximum of over 2.2 million lbs. landed in 1998 (Figure 42). Effort was relatively stable around ~25,000 annual fishing trips for the fishery from 1985-2000, but subsequently decreased to a low of just over 15,000 trips in

2006; after another increase back to original levels in the early-2010s, effort reached a minimum of just over 14,000 trips in 2016 (Figure 42). CPUE has displayed a slight increase over the course of the time series and the minimum recorded value was 36.7 lbs./trips in first year of the evaluated time series,1985 (Figure 42).

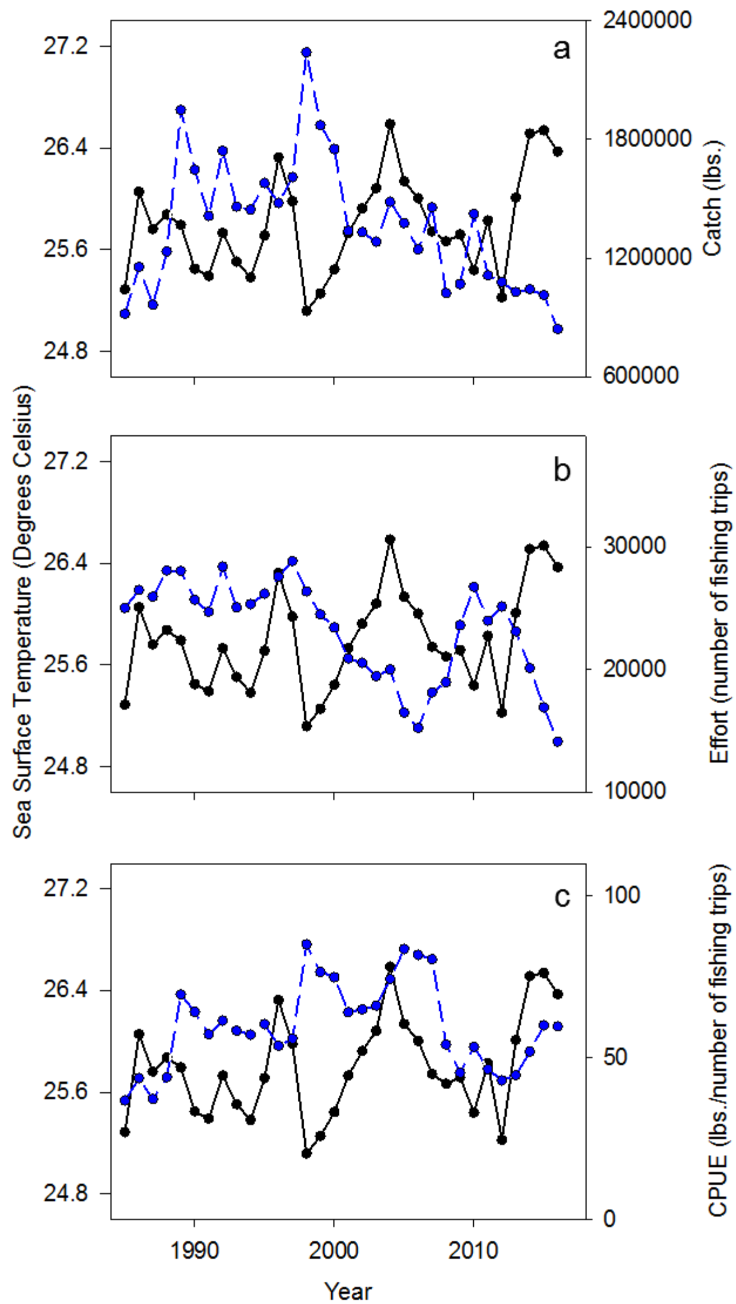

Figure 42. Time series of total annual catch (lbs.; blue; **[a]), effort (number of annual fishing trips; [b]), and CPUE (lbs./number of trips;** black; **[c]) for the MHI commercial coral reef fishery plotted with average annual** SST **(°C) from 1985-2016.**

In performing comparisons between fishery parameters and environmental variables such as SST, data were grouped based on taxa categories used in data collection while ensuring the longest, most contiguous time series possible. Table 84 displays the different dominant taxa groups considered as well as the scientific, common, and Hawaiian names of the species of which they are comprised.

Table 84. List of taxa recorded in MHI commercial catch data considered for these analyses.

Taxa code	Scientific Name	Family	Common Name	Hawaiian Name
PUALU	*Acanthurus blochii, xanthopterus*	Acanthuridae	ringtail surgeonfish	pualu
PALANI	*Acanthurus dussumieri*	Acanthuridae	eyestripe surgeonfish	palani
KALA	*Naso annulatus, brevirostris, unicornis*	Acanthuridae	whitemargin, shore-nosed, bluespine unicornfish	kala
ULUA	*Caranx ignobilis*	Carangidae	giant, bluefin trevally	ulua
AKULE	*Selar crumenophthalmus*	Carangidae	bigeye scad	akule
OPELU	*Decapterus macarellus*	Carangidae	mackerel scad	opelu
AHOLE	*Kuhila sanvicensis*	Kuhliidae	Hawaiian flagtail	aholehole
TOAU	*Lutjanus fulvus*	Lutjanidae	blacktail snapper	to'au
TAAPE	*Lutjanus kasmira*	Lutjanidae	bluestripe snapper	ta'ape
WEKE	*Mullidae spp. (Mulloidichthys flavolineatus, vanicolensis,* etc)	Mullidae	yellowstripe, red goatfish	weke'a, weke 'ula
MOANO	*Parupeneus* spp. (*misc*)	Mullidae	goatfish	-
KUMU	*Parupeneus porphyreus*	Mullidae	white-saddle goatfish	kumu
UHU	*Scarus* spp. (*Chlorurus perspecillatu, sprilurus; Scarus dubius, psittacus, rubroviolaceus, etc.*)	Scaridae	misc. parrotfish	uhu - ponuhunuhu, uhu uliuli, lauia, uh 'ele 'ele
MU	*Monotaxias grandoculis*	Lethrinidae	bigeye bream	mu

Multiple linear regressions and correlation analyses were performed on time series of commercial coral reef fishery CPUE and annual mean SST from the MHI (Table 85). Analyses measuring the association between SST and total CPUE for the entirety of the commercial coral reef fishery in the MHI showed no general relationship between 1985 and 2016 (R^2=0.03, p=0.36; Table 85; Figure 43).

Table 85. Correlation coefficients (*r*) between commercial coral reef fishery CPUE and SST (in °C) in the MHI for 14 top taxa harvested from 1985-2016. Significant correlations are indicated in bold (α=0.05).

Taxa Code	Total CPUE	PUALU	PALANI	KALA	ULUA	AKULE	OPELU	AHOLE	TOAU	TAAPE	WEKE	MOANO	KUMU	UHU	MU
n = 28															
p	0.36	0.33	0.08	0.18	0.09	0.26	0.12	0.76	0.58	0.76	**0.01**	0.80	0.16	0.76	0.48
r	0.18	0.19	0.34	0.26	-0.33	0.22	0.30	0.06	-0.11	0.06	**0.46**	-0.05	-0.27	0.06	0.14
R^2	0.03	0.03	0.12	0.07	0.11	0.05	0.09	0.00	0.01	0.00	**0.21**	0.00	0.07	0.00	0.02

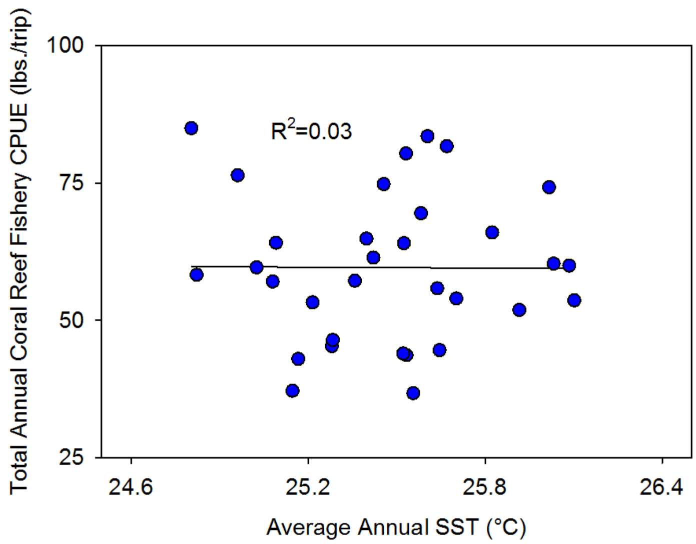

Figure 43. Linear regression showing the correlation between total annual CPUE for the commercial coral reef fishery and average annual sea surface temperature (°C) in the MHI from 1985-2016.

3.3.3 Relationship with Taxa Groups

In performing comparison analyses on time series of CPUE for prevalent taxa in the MHI commercial coral reef fishery, it was found that only weke's CPUE data showed a statistically significant correlation with SST (Table 85). The relationship between the weke taxa group and average annual SST was shown to be statistically significant in a positive manner such that for every degree Celsius of temperature increase, CPUE would approximately increase by 17 lbs./trip when harvesting weke ($R^2 = 0.21$, $p = 0.01$; Table 81 ; Figure 44). The next two strongest associations uncovered, palani and ulua, did not hold the same significance as the weke association did, but both came relatively close to the statistical significance threshold of $p = 0.05$. The palani taxa group had a positive association with SST ($R^2 = 0.12$, $p = 0.08$), whereas ulua displayed a negative relationship ($R^2 = 0.11$, $p = 0.09$; Table 85; Figure 44).

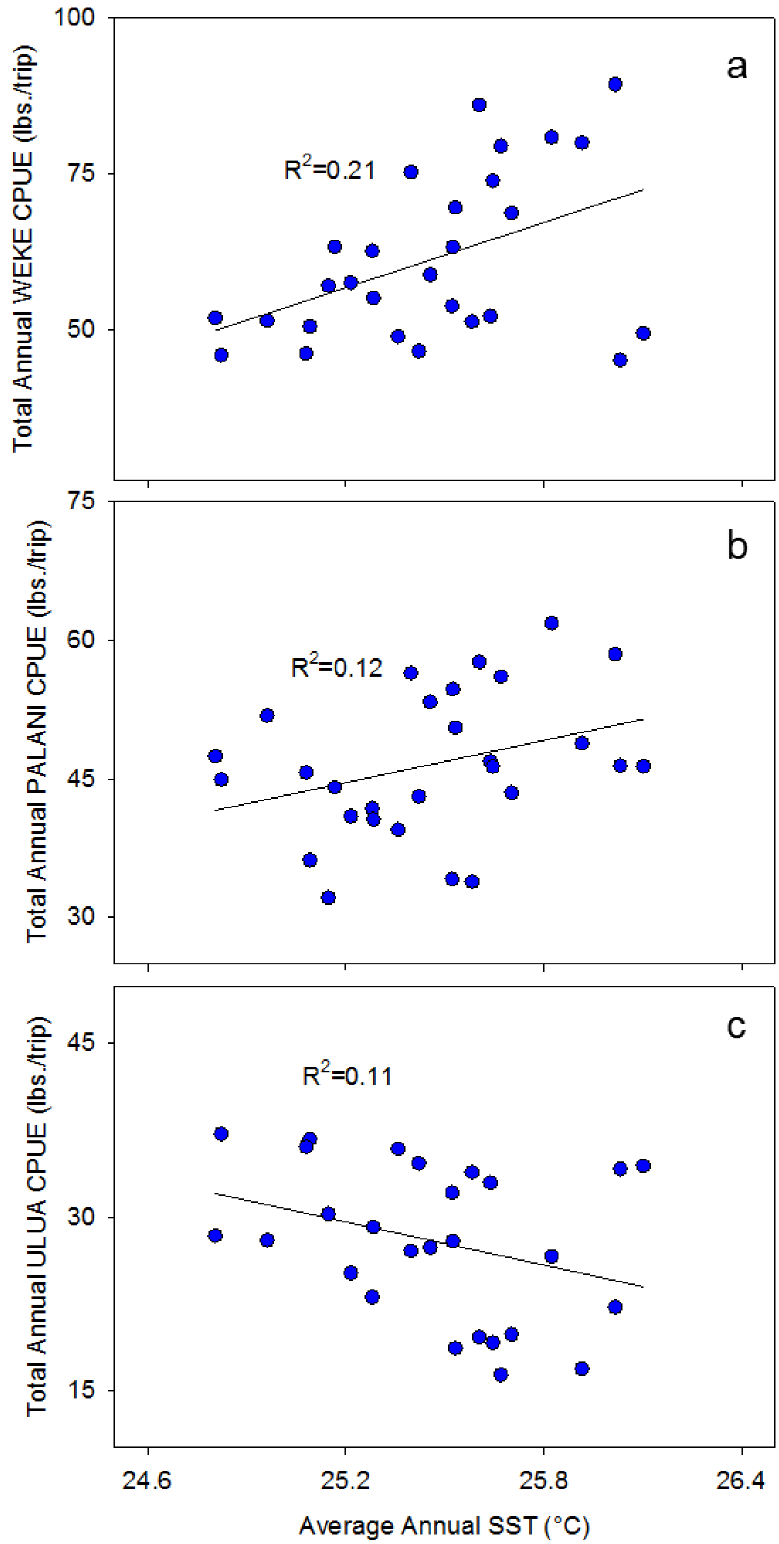

Figure 44. Linear regressions showing the three top correlations between total annual CPUE (lbs./number of trips) for the MHI commercial coral reef fishery and average annual sea surface temperature (°C) for (a) weke, (b) palani, and (c) ulua from 1985-2016.

3.4 PRIMARY PRODUCTIVITY

3.4.1 Trends in Primary Productivity

Concentrations of the pigment chlorophyll-*a* are frequently used as an index of phytoplankton biomass to represent primary production, are a commonly utilized tool in identifying eutrophication, and are noted to be among the highest priority fishery ecosystem relationships in the WPR by participants of the Workshop as well (Islam and Tanaka, 2004). In Pacific regions where interannual precipitation and associated coastal runoff are relatively high, the physio-chemistry of nearshore reefs can especially be impacted by nutrient input accompanying precipitation and result in increased primary production (Ansell *et al*., 1996).

Long-term changes in regional primary productivity have the potential to change reef fish population abundance due to the susceptibility of these assemblages in shallow areas of coastal reefs to variations in water chemistry, especially when combined with the variability of other environmental parameters like sea surface temperature (Kitiona *et al.*, 2016). For example, it has been suggested that warming ocean temperatures coupled with decreasing environmental productivity, likely due to a reduction in upwelling that isolated nutrients at depth, led to waning reef fish assemblages in the Southern California Bight (Roemmich and McGowan, 1995). With recent progress in satellite and fluorometric measurements of oceanic surface waters, time series of global and regional primary production generated using chlorophyll-*a* concentration estimates have become increasingly available, and are commonly used for evaluating the impact of environmental productivity on reef fish population abundance and the marine food web in general (Behrenfed *et al*., 2006; Messié and Radenac, 2006). Data for the study at hand were gathered from the Hawaii Ocean Time series CO_2 system data products from readings at Station ALOHA for the MHI only (see Dore *et al*., 2009).

Uncertainty levels were relatively high in evaluations including chlorophyll-*a* concentrations due to the nature of incorporating phase lag and not smoothing the catch data as is typically done for creel survey information. The largest issue in performing comparison analyses between catch levels from reef fisheries in American Samoa and fluorometric chlorophyll-*a* concentrations was the relatively short time series (i.e. small sample size) muddying any signals that might have been teased out. Robust, homogenous time series highlighting inter-decadal patterns in these regions were difficult to obtain due to time series merging several sources of chlorophyll concentration information to elongate the range of continuous data. For example, the ESA's Ocean Colour Climate Change Initiate dataset only permitted the use of less than two decades of data when evaluating the territories with the incorporation of phase lag. The length of the applied lag has a large impact in the patterns observed, so the relatively short extent of the available time series may obfuscate some of the identified relationships.

Figure N shows the fluorometric chlorophyll-*a* concentration time series for the MHI integrated from 0-200 meters depth in the water column from 1989-2015. While concentrations of chlorophyll-*a* seem to have been slightly increasing over the last several decades, the time series was relatively variable and the positive slope of the linear regression line was not statistically significant (CV = 10.2; $R^2 = 0.16$; Figure 45). The most recent years of recorded data had relatively high pigment concentrations, though the highest recorded level of chlorophyll-*a* (~30 mg/m^2) was observed in the first year of available data for the time series (1989; Figure 45). The average chlorophyll-*a* level integrated over the top 200 meters of the water column at Station

ALOHA was 23.8 mg/m^2, with the lowest recorded concentrations of fluorometric chlorophyll-*a* over the course of the time series being recorded in the year 1996 (18.6 mg/m^2; Figure 45).

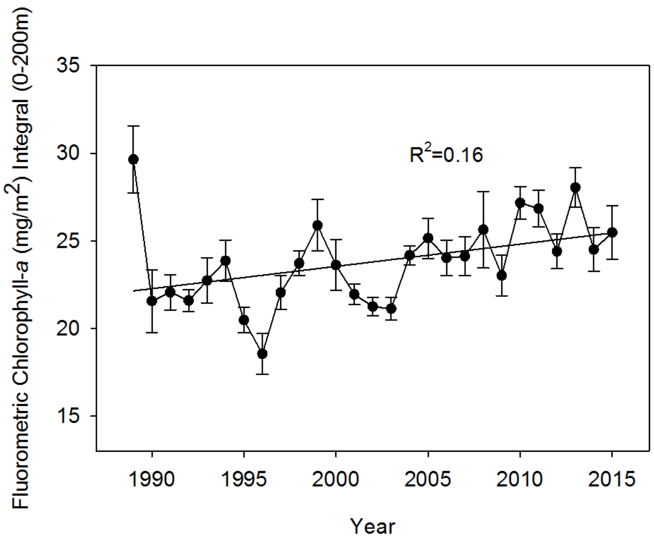

Figure 45. Time series of fluorometric chlorophyll-*a* concentrations (mg/m^2) integrated from 0-200m depth in the water column and associated intra-annual standard error at Station ALOHA (HOT 1-288) from 1989-2015 (CV=10.2).

3.4.2 Relationship with Entire Commercial Reef Fishery

Plots depicting comparisons of time series of the same chlorophyll concentration statistics and annual CPUE for the MHI commercial coral reef fishery from 1989-2013 are shown in Figure 46. The time series are two years shorter than the range of available data due to the implementation of two years of phase lag. The data displayed a pattern in which the years from 2000-2010 had relatively high CPUE levels (up to nearly 85 lbs./trip), but records available from years immediately before and after were notably lower (50-60 lbs./trip; Figure 46). The lowest CPUE was approximately 43 lbs./trip and was recorded in 2012 (Figure 46).

After conducting linear regressions and correlation analyses on time series of the MHI commercial coral reef fishery CPUE lagged by two years with fluorometric chlorophyll-*a* concentrations (mg/m^2) integrated from 0-200m depth in the water column, it was found that the association between these chlorophyll concentrations and total CPUE for all taxa was significantly negative between 1989 and 2013 (r = -0.44, p = 0.02; Table 86; Figure 47). The slope of the regression line was relatively gentle, however, and for every increase of 1 mg/m^2 in chlorophyll-*a* concentration integrated over the top 200 meters of the water column, CPUE would approximately decrease nearly10 lbs./trip two years later when considering the entirety of the MHI reef fishery (R^2 = 0.19, p = 0.02; Table 86; Figure 47).

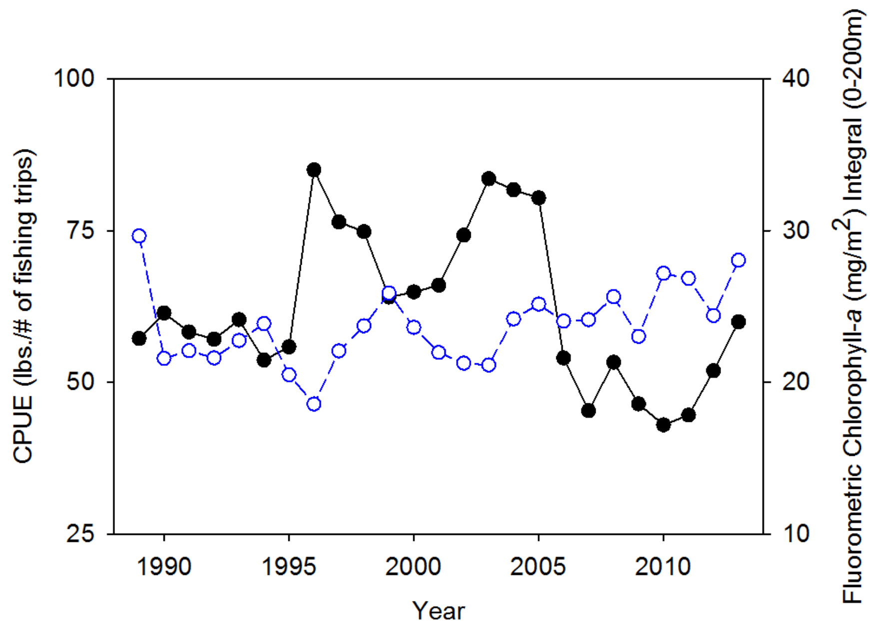

Figure 46. Comparison of CPUE (lbs./number of annual fishing trips; black**) with two years of time lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^2**; blue**) integrated from 0-200m depth in the water column from Station ALOHA (HOT 1-288) for the years 1989-2013 (*r* = -0.44).**

Table 86. Correlation coefficients (*r*) from comparisons of time series of MHI commercial coral reef fishery CPUE and fluorometric chlorophyll-*a* concentrations (mg/m^2) integrated from 0-200m depth in the water column from Station ALOHA for 14 top taxa harvested from 1989-2013. Significant correlations are indicated in bold (α=0.05).

Taxa Code	Total CPUE	PUALU	PALANI	KALA	ULUA	AKULE	OPELU	AHOLE	TOAU	TAAPE	WEKE	MOANO	KUMU	UHU	MU
n = 26															
p	**0.02**	0.11	0.53	0.09	0.41	**0.05**	0.81	0.85	0.85	**0.00**	0.88	0.92	0.11	0.09	0.96
r	**-0.44**	0.32	-0.13	0.34	-0.17	**-0.39**	0.05	-0.04	0.04	**-0.66**	0.03	0.02	0.32	0.34	0.01
R^2	**0.19**	0.10	0.02	0.12	0.03	**0.15**	0.00	0.00	0.00	**0.43**	0.00	0.00	0.11	0.12	0.00

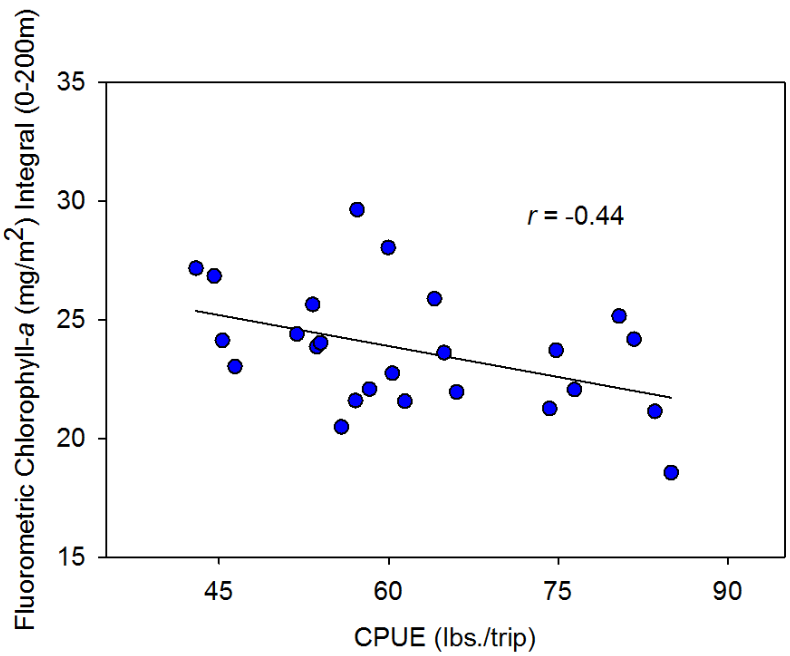

Figure 47. Linear regression showing between total annual CPUE (lbs./number of annual fishing trips) for the MHI commercial coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^2) integrated from 0-200m depth in the water column from Station ALOHA (HOT 1-288) from 1989-2013.

3.4.3 Relationship with Taxa Groups

Multiple linear regression and correlation analyses were performed in the same way for time series of CPUE for dominant taxa in the Hawaiian commercial reef fishery, and only two of the 14 evaluated taxa showed statistically significant associations with local chlorophyll concentrations: ta'ape and akule (Table 86). The relationship between the CPUE of species in the ta'ape group and chlorophyll concentration was shown to be significantly negative such that for every increase of 1 mg/m^2 in chlorophyll-*a* concentration, CPUE would decrease by approximately 1.6 lbs./trip lagged by two years (R^2=0.43, p = 0.00; Table 86; Figure 48). The relationship between CPUE of akule and chlorophyll was also shown to be significantly negative, though not to as great of an extent. Generally, with an increase of 1 mg/m^2 in chlorophyll-*a* concentration integrated over the top 200 meters of the water column in the MHI, commercial CPUE would decrease by approximately 13 lbs./trip after two years for akule (R^2=0.27, p = 0.00; Table 86; Figure 48). The next strongest associations, though not significant, belong to comparisons involving pualu, kala, kumu, and uhu (R^2=0.10-0.12, p=0.09-0.11; Figure 48); all four of these potential fishery ecosystem relationships, however, were positive (Table 86).

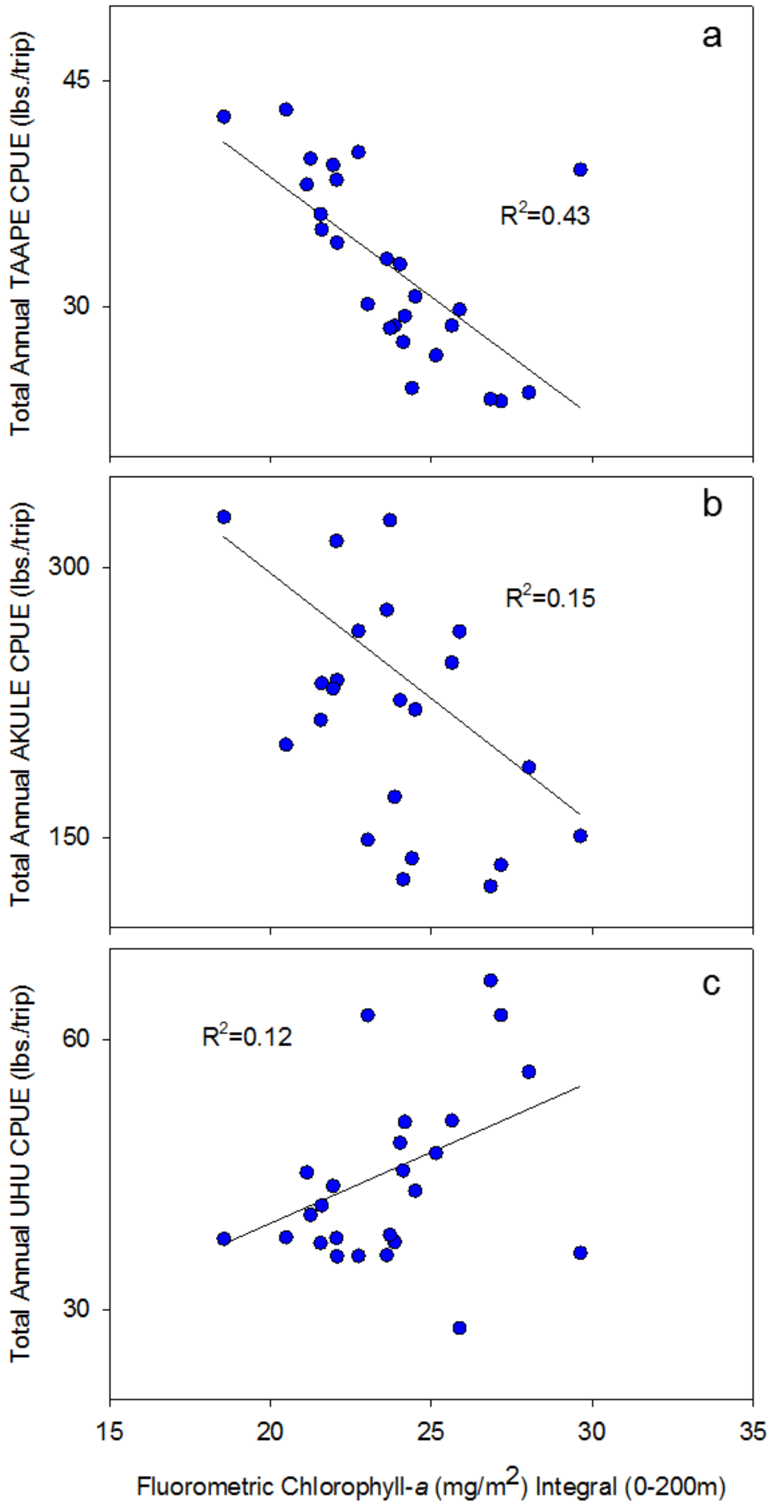

Figure 48. Linear regressions showing the three top correlations between total annual CPUE (lbs./number of annual fishing trips) for the MHI commercial coral reef fishery with phase lag (t+2 years) and fluorometric chlorophyll-*a* concentrations (mg/m^2) integrated from 0-200m depth in the water column from Station ALOHA (HOT 1-288) for (a) ta‘ape, (b) akule, and (c) uhu from 1989-2013.

3.5 MULTIVARIATE ASESSMENTS OF OTHER ECOSYSTEM VARIABLES

3.5.1 Non-metric Multidimensional Scaling

There were several other prioritized fishery ecosystem relationships for coral reefs in the American Samoa involving environmental parameters that were not to be addressed in this initial evaluation including: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), sea level height, pH, dissolved oxygen, and salinity. Further descriptions of these climate and oceanic indicators are available in Section 2.5.3. Sea surface height data were aggregated from the Ocean Service, Tides, and Currents, and Sea Level database operated (NOAA/NOS/CO-OPS). Basin-wide data ONI were taken from NOAA's Nation Centers for Environmental Information- Equatorial Pacific Sea Surface Temperature Database (Climate Prediction Center Internet Team 2015). Similarly, PDO data were obtained from NOAA's Earth System Research Laboratory Physical Sciences Division originally derived from OI.v1 and OI.v2 SST parameters (NOAA PDO). Salinity data for American Samoa were gathered from Simple Ocean Data Assimilation (SODA) version 3.3.1 (Carton and Giese, 2008). Rainfall estimates were obtained through the local National Weather Service in American Samoa (NWS-AS).

Non-metric multidimensional scaling (NMS), a form of multivariate analysis that orders sample units along synthetic axes to reveal patterns of composition and relative abundance, is most commonly utilized when looking to identify patterns in heterogeneous species response data (Peck, 2016). For this study, NMS was used to help identify associations between coral reef fishery parameters and ecological/environmental factors using the program PC-ORD 7. To ensure the same length of time series for all catch and environmental variables considered thus allowing for the general inclusion of more parameters, data was analyzed from 1989 to 2015. The generated axes represented the best fit of patterns of redundancy in the catch data used as input, and the resulting ordination scores were a rank-order depiction of associations in the original dataset.

NMS produces robust results even in the presence of outliers by avoiding parametric and distributional assumptions (Peck, 2016). The only assumption to be met in NMS is that the relationship between the original rank ordered distances between sample units and the reduced distances in the final solution should be monotonic; that is, the slope of the association between the two is flat or positive, as determined by the stress statistic. In the most general terms, interpretable and reliable ordination axes have stress less than 10 up to 25 for datasets with large sample size, but large stress scores (i.e. greater than 30) may suggest that the final ordination results have little association with the original data matrix. Additionally, NMS ordination scores vary depending on the number of dimensions/axes designated to be solved (Peck, 2016). Dimensionality (i.e. number of axes for the final solution) for each test was identified though PC-ORD result recommendations based on final stress being lower than that for 95% of randomized runs (i.e. $p \leq 0.05$). Tau is a statistic that represents the rank correlations of the ordination scores to the original data matrices, and was used to identify explanatory variables with associations to the ordination axes. For the MHI test, data from 13 species/taxa groups from 1989 - 2015 (27 years) were included along with 10 variables of environmental data collected during the same time period (see Table 84).

The resulting ordination scores from NMS analyses performed on commercial catch data and a range of environmental parameters from 1989-2015 in the MHI selected a two-dimensional solution with 100% orthogonal axes, accounting for 98.3% of variance observed in the commercial coral reef fishery data (Figure 49). The results of the analysis had low final stress (5.26) relative to the average stress from randomizations (7.47), supporting the suggestion that the two-dimensional solution has viable results.

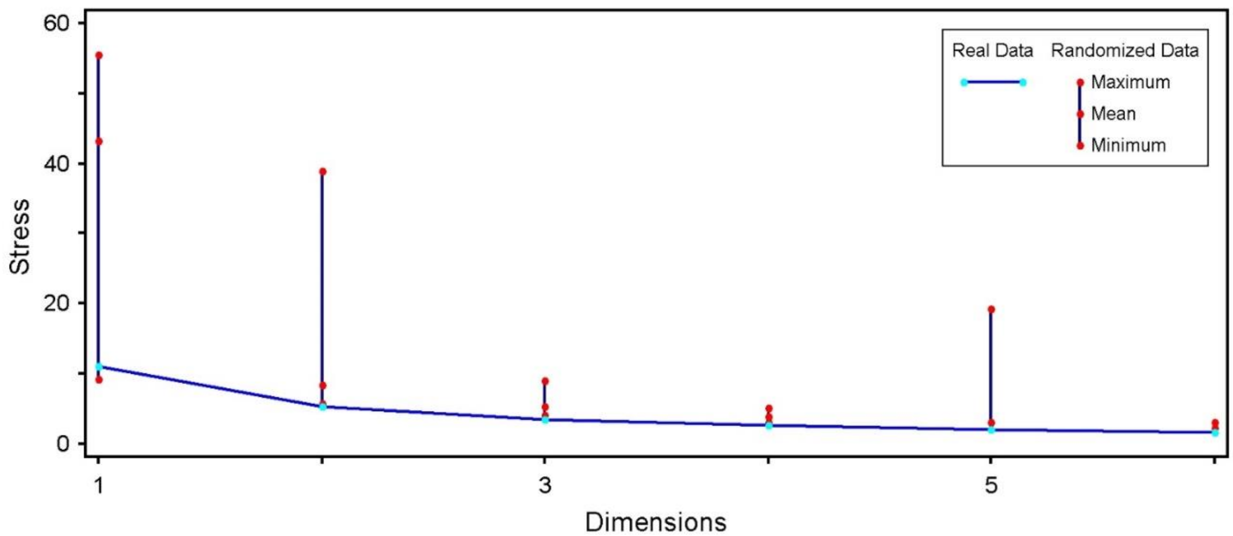

Figure 49. NMS scree plot showing a stress test to determine dimensionality for the final solution. A two-axis solution was recommended.

The final ordination scores for the taxa were crudely clustered in ordination space, with individual outliers and others with variable distance between them (Figure 50). Replicate NMS runs had similar stress levels for the final generated result. The distribution of final ordination scores for evaluated MHI taxa showed several environmental parameters that have significant associations with the selected axes. SST (tau = 0.38) and DO (tau = 0.35) were both positively associated with the first axis ($r^2 = 0.94$), whereas pH displayed a significantly negative relationship with the axis (tau = -0.46). Axis 2 ($r^2 = 0.04$), was shown to be most closely associated positively with pH (tau = 0.37) and negatively with salinity (tau = -0.37; Figure 50). Analyses including time series of pH levels and/or associated factors in Hawaii may be useful going forward.

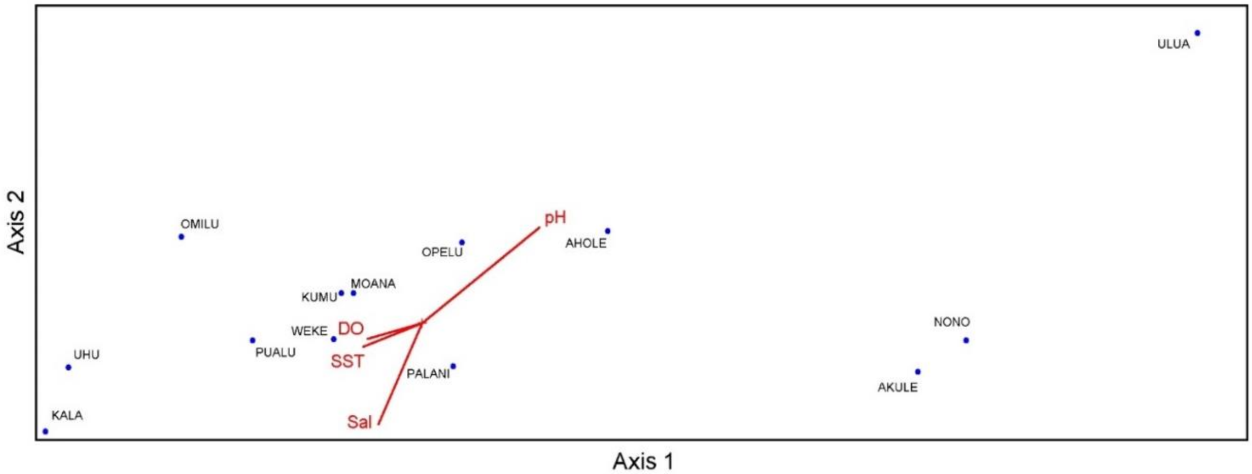

Figure 50. Two-dimensional scatterplot overlaid with a joint bi-plot depicting ordination scores resulting from an NMS analysis on commercial catch data and prominent environmental parameters in the MHI from 1989-2015.

Ultimately, stress values for all analyses were relatively low, suggesting that the generated ordination scores were robust and useful for interpretation relative to the ordination axes. Nearly all included environmental parameters had a statistically significant relationship with at least one ordination axis in at least one of the final solutions, suggesting that these parameters likely intertwine in complicated processes to produce observed impacts on coral reef fisheries in the U.S. Western Pacific. Though a fishery ecosystem relationship may have not been explicitly identified in NMS runs of this preliminary evaluation, it does not preclude the possibility that an association may still exist.

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APPENDIX A: LIST OF MANAGEMENT UNIT SPECIES

HAWAII

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

HDAR Species Code	Species Name	Scientific Name
19	Opakapaka	*Pristipomoides filamentosus*
22	Onaga	*Etelis coruscans*
21/36	Ehu	*Etelis carbunculus*
15	Hapuupuu	*Epinephelus quernus*
97	Gindai	*Pristipomoides zonatus*
17	Kalekale	*Pristipomoides seiboldii*
58	Lehi	*Aphareus rutilans*

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

HDAR Species Code	Species Name	Scientific Name
208	yellowtail snapper (kalekale)	*Pristipomoides auricilla*
20	gray jobfish (uku)	*Aprion virescens*
205	giant trevally (white ulua)	*Caranx ignoblis*
202	black trevally (black ulua)	*Caranx lugubris*
114	taape	*Lutjanis kasmira*
16	greater amberjack (kahala)	*Seriola dumerili*
200	pig lipped trevally (butaguchi)	*Pseudocaranx dentex*

Note: Taape (*Lutjanis kasmira*) is listed in the Hawaii CREMUS group, Lutjanidae (Snapper).
Kahala (*Seriola rivoliana*) is listed in the Hawaii CREMUS group, Carangidae (Jacks).
MHI Deep 7 bottomfish not inlcuded in the 2012 ACL tracking exercise.
Seamount groundfish not included in the 2012 ACL tracking exercise.

3. Crustacean deep-water shrimp complex (non-FSSI)

HDAR Species Code	Species Name	Scientific Name
708	deepwater shrimp	*Heterocarpus* spp.
709	deepwater shrimp (ensifer)	*Heterocarpus* spp.

4. Crustacean spiny lobster complex (non-FSSI)

HDAR Species Code	Species Name	Scientific Name
716	spiny lobster	*Panulirus marginatus*
717	spiny lobster	*Panulirus penicillatus*

5. Crustacean slipper lobster complex (non-FSSI)

HDAR Species Code	Species Name	Scientific Name
718	Slipper lobster	Scyllaridae

6. Crustacean Kona crab complex (non-FSSI)

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

7. Auau Channel Black coral complex (non-FSSI)

HDAR Species Code	Species Name	Scientific Name
860	Black Coral	*Antipathes griggi*
860	Black Coral	*Antipathes dichotoma*
860	Black Coral	*Antipathes grandis*
860	Black Coral	*Antipathes ulex*

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

HDAR Species Code	Species Name	Scientific Name
871	Pink coral	*Corallium secundum*
872	Pink coral	*Corallium regale*
873	Pink coral	*Corallium laauense*
891	Bamboo coral	*Lepidisis olapa*
892	Bamboo coral	*Acanella* spp.
880/881	Gold Coral	*Gerardia* spp.
882	Gold Coral	*Callogorgia gilberti*
883	Gold Coral	*Narella* spp.
884	Gold Coral	*Calyptrophora* spp.

9. Coral reef ecosystem (non-FSSI)

HDAR Species Code	Species Name	Scientific Name	Grouping
28	Bigeye Scad (Adult)	*Selar crumenophthalmus*	Akule
37	Bigeye Scad (Juvenile)	*Selar crumenophthalmus*	Akule
81	OPELU	*Decapterus* spp.	Opelu
16	BARRED JACK	*Carangoides ferdau*	Carangidae
18	DOBE	*Caranx (Urapsis) helvolus*	Carangidae
23	KAGAMI	*Alectis ciliaris*	Carangidae
48	KAHALA	*Seriola rivoliana*	Carangidae
56	KAMANU	*Elagatis bipinnulata*	Carangidae
79	LAE	*Scomberoides lysan,*	Carangidae
79	LAE	*Scomberoides sancti-petri*	Carangidae
89	NO-BITE	*Caranx equula*	Carangidae
104	OMAKA	*Atule mata*	Carangidae
112	OMILU	*Caranx melampygus*	Carangidae
203	PAOPAO	*Gnathanodon speciosus*	Carangidae
204	PAPA	*Carangoides orthogramus*	Carangidae
220	PAPIO, ULUA (MISC.)	*Carangidae*	Carangidae
221	SASA	*Caranx sexafaciatus*	Carangidae
52	KUMU	*Parupeneus porphyeus*	Mullidae
110	MALU	*Parupeneus pleurostigma*	Mullidae

68	MOANA	*Parupeneus spp.*	Mullidae
206	MOANO KALE	*Parupeneus cyclostomus*	Mullidae
70	MOELUA; GOAT FISH (RED)	*Mulloidichthys sp.*	Mullidae
121	MUNU	*Parupeneus bifasciatus*	Mullidae
103	WEKE (MISC.)	*Mullidae*	Mullidae
128	WEKE A'A	*Mulloidichthys flavolineatus*	Mullidae
24	WEKE NONO	*Mulloidichthys pflugeri*	Mullidae
122	WEKE PUEO	*Upeneus arge*	Mullidae
127	WEKE-ULA	*Mulloidichthys vanicolensis*	Mullidae
47	KALA	*Naso annulatus*	Acanthuridae
47	KALA	*Naso brevirostris*	Acanthuridae
47	KALA	*Naso Unicornus*	Acanthuridae
125	KALALEI	*Naso lituratus*	Acanthuridae
51	KOLE	*Ctenochaetus strigosus*	Acanthuridae
59	MAIII	*Acanthurus nigrofuscus*	Acanthuridae
60	MAIKO	*Acanthurus nigroris*	Acanthuridae
61	MAIKOIKO	*Acanthurus leucopareius*	Acanthuridae
64	MANINI	*Acanthurus triostegus*	Acanthuridae
72	NAENAE	*Acanthurus olivaceus*	Acanthuridae
124	OPELU KALA	*Naso hexacanthus*	Acanthuridae
85	PAKUIKUI	*Acanthurus achilles*	Acanthuridae
86	PALANI	*Acanthurus dussumieri*	Acanthuridae
92	PUALU	*Acanthurus blochii,*	Acanthuridae
92	PUALU	*A. xanthopterus*	Acanthuridae
83	YELLOW TANG	*Zebrasoma flavescens*	Acanthuridae
126	API	*Acanturus guttus*	Acanthuridae
129	BLACK KOLE	*Ctenochaetus hawaiiensis*	Acanthuridae
209	GOLDEN KALI	*Erythrocles schegelii*	Lutjanidae
123	GURUTSU, GOROTSUKI	*Aphareus furca*	Lutjanidae
207	RANDALL'S SNAPPER	*Randallichthys filamentosus*	Lutjanidae
	TAAPE	*Lutjanus kasmira*	Lutjanidae
115	TOAU	*Lutjanus fulvus*	Lutjanidae
38	WAHANUI	*Aphareus furcatus*	Lutjanidae
29	ALAIHI	Squirrelfish	Holocentridae
101	ALAIHI MAMA	Squirrelfish	Holocentridae
100	MENPACHI	Squirrelfish	Holocentridae
90	PAUU	Squirrelfish	Holocentridae
30	AMAAMA	*Mugil cephalus*	Mugilidae

32	SUMMER MULLET	*Mugil sp.*	Mugilidae
726	HE'E (DAY TAKO)	*Octopus cyanea*	Mollusk
727	HE'E PU LOA	*Octopus ornatus*	Mollusk
720	OLEPE	*Albula glossodonta*	Mollusk
721	OCTOPUS	*Octopus* spp.	Mollusk
87	PANUHUNUHU	*Scarus* spp.	Scaridae
88	PANUNU	*Scarus* spp.	Scaridae
96	UHU (MISC.)	*Catalomus* spp.	Scaridae
710	A'AMA	*Graspus tenuicrustatus*	CRE-crustaceans
711	BLUE PINCHER CRAB	*Callinectes sapidus*	CRE-crustaceans
700	CRAB (MISC.)	n/a	CRE-crustaceans
703	HAWAIIAN CRAB	*Podophthalmus vigil*	CRE-crustaceans
702	KUAHONU CRAB	*Portunus sanguinolentus*	CRE-crustaceans
713	METABETAEUS LOHENA	*Metabetaeus lohena*	CRE-crustaceans
705	MISC. SHRIMP/PRAWN	n/a	CRE-crustaceans
712	OPAE ULA	*Halocaridina rubra*	CRE-crustaceans
704	SAMOAN CRAB	*Scylla serrata*	CRE-crustaceans
65	SHARK (MISC.) MANO, SPINY DOGFISH, GREY REEF	Carcharhinidae	Carcharhinidae
66	HAMMERHEAD SHARK	Spheyrnidae	Carcharhinidae
753	HA'UKE'UKE	*Colobocentrotus atratus*	Other Invertebrates
754	HAWAE	*Tripneustes gratilla*	Other Invertebrates
751	WANA	*Diadema* sp.	Other Invertebrates
751	WANA	*Echinothrix* sp.	Other Invertebrates
752	NAMAKO	Holothuroidea	Other Invertebrates
755	SLATE PENCIL URCHINS	*Heterocentrotus mammillatus*	Other Invertebrates
27	AHOLEHOLE	*Kuhlia sandvicensis*	Other CRE Finfish
31	AWA	*Chanos chanos*	Other CRE Finfish
33	AWAAWA	*Elops hawaiensis*	Other CRE Finfish
34	AWEOWEO	*Heteropriacanthus cruentatus*	Other CRE Finfish
133	GOLD SPOT HERRING	*Herklotsichthys quadrimaculatus*	Other CRE Finfish
39	HAULIULI	*Gempylus serpens*	Other CRE Finfish
300	HOGO	*Pontinus macrocephalus*	Other CRE Finfish
43	HUMUHUMU	Balistidae	Other CRE Finfish
44	IAO	*Pranesus insularum*	Other CRE Finfish
45	IHEIHE	Hemiramphidae	Other CRE Finfish
46	KAKU	*Sphyraena barracuda*	Other CRE Finfish

49	KAWALEA	*Sphyraena helleri*	Other CRE Finfish
53	KUPIPI	*Abudefduf sordidus*	Other CRE Finfish
57	LAUWILIWILI	*Chaetodon auriga*	Other CRE Finfish
77	LOULU	Monacanthidae	Other CRE Finfish
67	MAKAIWA	*Etrumeus micropus*	Other CRE Finfish
62	MALOLO	Exocoetidae	Other CRE Finfish
63	MA'O MA'O	*Abudefduf abdominalis*	Other CRE Finfish
69	MOI	*Polydactylus sexfilis*	Other CRE Finfish
109	MOLA MOLA	Mola mola	Other CRE Finfish
73	NEHU	*Stolephorus purpureus*	Other CRE Finfish
75	NOHU	*Scorpaenopsis* spp.	Other CRE Finfish
76	NUNU	*Aulostomus chinensis*	Other CRE Finfish
78	OIO	*Gracilaria parvispora*	Other CRE Finfish
80	OOPU HUE	*Diodon* spp.	Other CRE Finfish
84	PAKII	*Bothus* spp.	Other CRE Finfish
91	PIHA	*Spratelloides delicatulus*	Other CRE Finfish
119	POO PAA	*Cirrhitus* spp.	Other CRE Finfish
93	PUHI (MISC.)	*Gymnothorax* spp.	Other CRE Finfish
95	PUHI (WHITE)	Muraenidae	Other CRE Finfish
725	PUPU	Congridae spp.	Other CRE Finfish
111	SABA	*Scomber japonicus*	Other CRE Finfish
113	TILAPIA	*Tilapia* sp.	Other CRE Finfish
99	UPAPALU	*Apogon kallopterus*	Other CRE Finfish
800	LIMU (MISC.)	*Gracilaria* spp.	Algae
801	LIMU KOHU	*Asparagopsis taxiformis*	Algae
802	MANAUEA	*Gracilaria coronopifolia*	Algae
803	OGO	*Aulostromus chinensis*	Algae
804	WAWAEIOLE	*Ulva fasciata*	Algae
74	NENUE	*Kyphosus bigibbus,*	Rudderfish
74	NENUE	*Kyphosus cinerescens*	Wrasse
25	A'AWA	*Bodianus bilunulatus*	Wrasse
35	WRASSE (MISC.)	Labridae	Wrasse
41	HILU	*Coris flavovittata*	Wrasse
42	HINALEA	*Thalassoma* spp.	Wrasse
54	KUPOUPOU	*Cheilio inermis*	Wrasse
55	LAENIHI	*Xyichthys pavo*	Wrasse
82	OPULE	*Anampses cuvier*	Wrasse
105	MALLATEA	Labridae	Wrasse

120	POOU	*Cheilinus unifasciatus*	Wrasse
	MU	*Monotaxis grandoculis*	Emperor
	ROI	*Cephalopholus arugs*	Grouper

APPENDIX B. LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT.

Table B-1. Protected species found or reasonably believed to be found in or near Hawai`i 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
Little Tern	*Sternula albifrons*	Not Listed	N/A	Breeding visitor in the NWHI	Pyle & Pyle 2009

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
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 haulout 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 Hawai`i and low level nesting on Maui and Hawai`i 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
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

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
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 Hawai`i 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 Hawai`i 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
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Hawai`i 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

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
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 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 Hawai`i 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
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

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
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 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.	77 FR 4170
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 http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm.

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APPENDIX C: CRUSTACEAN LIFE HISTORY AND HABITAT REVIEW

OVERVIEW

This report presents a literature review of the life history and habitat requirements for each life stage for four species of reef-associated crustaceans that are landed in commercial fisheries Western Pacific region: two species of spiny lobster (*Panulirus marginatus* and *Scyllarides squammosus*), scaly slipper lobster (*Scyllarides squammosus*), and Kona crab (*Ranina ranina*).The most up to date information on the species distribution, fisheries in the Western Pacific Region, and life history is summarized. Tables summarizing the multiple dimensions of habitat use for each life stage (egg, larvae, post-larvae, juvenile, and adult) are also provided. The purpose of this report is to provide guidance in reviewing and updating essential fish habitat for reef associated crustaceans in the Western Pacific region.

1. HAWAIIAN SPINY LOBSTER (*PANULIRUS MARGINATUS)*

1.1. GENERAL DESCRIPTION AND DISTRIBUTION

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida, 1986; FAO, 1991).The Hawaiian spiny lobster (*Panulirus marginatus*), also known as ula and banded spiny lobster, is endemic to the Hawaiian Archipelago and Johnston Atoll (Brock, 1973; Polovina and Moffitt, 1995). The highest abundances of spiny lobster are found in the Northwestern Hawaiian Islands (NWHI; Uchida and Tagami, 1984). A single male spiny lobster has been collected in the shallow waters of Johnston Atoll, but it is unknown if an established reproducing population exists here (Brock, 1973).

Although *P. marginatus* has a long pelagic larval duration, the spiny lobster exhibits significant population structure across the Hawaiian Archipelago with regional differentiation between the NWHI and main Hawaiian islands (MHI; Lacchei *et al.,* 2014). Larval exchange between populations in the MHI and NWHI is minimal and if it does occur, it is more likely larvae are transported from the MHI to NWHI than vice versa (Lacchei *et al.,* 2013).

From the mid-1970s to 1999 spiny lobsters were targeted in a commercial trap fishery in the NWHI (O'Malley, 2004). The NWHI commercial fishery was composed of 9-14 vessels, setting about 80 traps per day and taking 3, approximately 8 week trips per year (Polovina and Mitchum, 1992). Total effort in the commercial fishery was approximately 1 million trap hauls per year (Polovina *et al.,* 1995). Necker Island and Maro Reef accounted for over 60% of all lobster landings (Polovina and Mitchum, 1992).

1.2. FISHERIES

In 1983, a requirement for NWHI commercial lobsters fishers to submit logbooks was implemented and the fishery was managed with a minimum size of 5 cm tail-width (7.5 cm carapace length or CL) and no trapping in areas < 18 m. The depth restriction was to minimize disturbance to the Hawaiian monk seal (Parrish and Polovina, 1994). In 1996, a retain all regulation was implemented and replaced the 5 cm tail width (TL) minimum size due to the high discard mortality rate.

The NWHI commercial spiny lobster fishery peaked in 1985 with total landings exceeding 2.5 million pounds. After 1985, CPUE began to steadily decline, which has been attributed to a number of causes. In 1990, there was a recruitment collapse, which was attributed to climate change and shifts in the ecosystem's productivity (Polovina *et al.,* 1995). After this recruitment collapse, fishing continued and reduced the spawning stock biomass to low levels (Polovina *et al.,* 1995). In 2000, NMFS closed the NWHI spiny lobster fishery due to increasing uncertainty in the assessment of the population; area-based commercial closures from the NWHI Coral Reef Ecosystem Reserve in 2001 and the complete prohibition on commercial fishing in the Papahānaumokuākea Marine National Monument in 2006 have maintained the closure. Since the closure of the commercial fishery in 2000, there has been no evidence that the NWHI spiny lobster population has recovered (O'Malley, 2011; Lacchei *et al.,* 2014).

Currently, fewer than three commercial fishers in the MHI land spiny lobster with traps (NOAA Fisheries, 2017a), and approximately 19 commercial dive fishers land spiny lobsters (NOAA Fisheries, 2017b). In 2015, 5,744 lbs. of spiny lobster where landed commercially in the MHI fishery (DAR, 2015). Spiny lobsters are also targeted and landed by recreational and subsistence fishers in the MHI, but the extent of this fishery is unknown (MacDonald and Thompson, 1987). Management for the spiny lobster in the MHI includes a closed season from May-August, no taking of female lobsters, no spearing, and a minimum size of 3.25 inch CL.

1.3. LIFE HISTORY

1.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Hawaiian spiny lobsters exhibit sexual dimorphism in growth with males growing faster than females (O'Malley, 2009). While temporal and spatial variation in growth rates for *Panulirus sp*. is uncommon, the temporal, spatial, and individual growth rates of spiny lobsters found in the NWHI is the highest that has ever been reported for any *Panulirus* species (O'Malley, 2009). The cause of the large variation in growth rates is unknown, but may be attributed to variability in prey regimes and/or environmental conditions (O'Malley *et al.,* 2012).

Growth in spiny lobsters is stepwise as they get larger by molting and difficult to describe with a continuous von Bertalanffy relationship (O'Malley and MacDonald, 2009). The molting process consists of 8 discrete stages (Lyle and MacDonald 1983). Mean annual growth rates of tagged male lobsters with a 75 mm CL varied between 3.55 to 15.85 mm, and the annual average growth rate of 70 mm CL tagged female lobsters varied between 1.866 mm to 15.84 mm (O'Malley and MacDonald, 2009).

Size at which female lobsters reach sexual maturity also varies spatially and temporally, and may be associated with density dependence (Polovina, 1989; DeMartini *et al.,* 2003). Estimates of onset of sexual maturity for females range between 57.99 mm CL and 74.8 mm CL (Polovina, 1989). The onset of female maturity was reportedly lower in banks after 10 years of heavy exploitation, which Polovina hypothesizes may be a compensatory response (Polovina, 1989).

Although the longevity of this species is not known, other tropical spiny lobster species live up to 20 years (Butler and MacDiarmid 2011). Annual natural mortality likely varies with size but is estimated on average to be 0.456 (Haight and Polovina, 1993)

1.3.2. REPRODUCTION

Female fecundity increases with both carapace length and tail-width (Honda, 1980; DeMartini *et al.,* 2003). Female lobsters have between 114,000 and 782,000 eggs per brood, and may have multiple broods per spawning season (DeMartini *et al.,* 2003). A 36% increase in average fecundity and a 5% increase in egg diameter was observed over a 30-year period and attributed to a compensatory response to decreased lobster densities and increased per capita food resources as a result of either natural cyclic declines in productivity and/or high exploitation rates from the commercial fishery (DeMartini *et al.,* 1993; DeMartini *et al.,* 2003). This increase in fecundity and egg size coincided with compensatory declines in size at maturity (DeMartini *et al.,* 2003).

Hawaiian spiny lobsters are dioecious and fertilization occurs externally (Uchida, 1986). Mature males will deposit a spermatophore on a mature females' abdomen (Uchida, 1986). Females then release the ova from the oviduct and simultaneously scratch and break the spermatophore open to release spermatozoa, which fertilize the eggs (WPRFMC, 1983). Females attach the fertilized eggs to setae of the female's pleopod. The eggs are visible and females carrying fertilized eggs on the pleopod are referred to as 'berried'. Females carry fertilized eggs for 30-40 days until they hatch into planktonic, pelagic larvae (Morris, 1968). Brooded eggs are orange when first extruded and change to a brown color before hatching (DeMartini *et al.,* 2003).

The spawning season of *P. marginatus* appears to vary within the NWHI chain. Around Nihoa, Necker Island, and French Frigate Shoals, ovigerous females occur in late summer and early winter; toward the northwestern end of the chain, ovigerous females are more abundant in early summer (Uchida *et al.,* 1980). Off O'ahu spawning has been throughout the year and peak activity is concentrated in May-August and low activity is apparent in November-January (McGinnis, 1972).

1.3.3. LARVAE AND RECRUITMENT

After hatching, pelagic phyllosoma larvae, drift in the ocean currents for 12 months and pass through 11 stages of development (MacDonald, 1986; Polovina and Moffitt, 1995). Larval phyllosoma make diurnal movements from 80-100 m during the day, to 10-20 m at night, and are found in high abundance on the surface at night during the new moon (Polovina and Moffitt 1995). Abundance of late stage phyllosomes are higher offshore (up to 25 nmi from 200 m contour) relative to the 200-m contour, which may be explained by either oceanographic currents and nearshore topography pushing larvae offshore and/or higher predation in nearshore areas (Polovina and Moffitt 1995). Although spiny lobsters have a long pelagic duration, banks differ substantially in the proportion of larvae they retain from resident spawners, as well as the portion of larvae they receive from other banks (Polovina *et al.,* 1999). Oceanographic processes such as the strength of the Subtropical Counter Current (SCC) at 26° N latitude, where it intersects with the Hawaiian Ridge and sea level height, play a large role in determining larval retention rates and survival of the pelagic phyllosoma. A high abundance of late stage larvae are found at 26° N suggesting recruitment is linked to the strength of the SCC (Polovina and Moffit, 1995).

This relationship is especially clear at Maro Reef in the NWHI, where a clear trend exists between sea level height and recruitment to the fishery 4 years later (Polovina *et al.,* 1995).

After 12 months, phyllosoma metamorphose into free swimming post-larval pueruli (Polovina and Moffitt, 1995). Pueruli actively swim to shallow, nearshore waters in preparation for settlement (MacDonald, 1986). Settlement is generally higher at the center of the Hawaiian Archipelago relative to the ends, and higher in the NWHI than the MHI (MacDonald, 1986). Other species of spiny lobster pueruli are capable horizontal, directed swimming of up to 40-60 km, but it is unknown how far pueruli of Hawaiian spiny lobster are able to move horizontally before settling (Pearce and Phillips, 1994). Large pulses in larvae settlement occur during new moon and first quarter lunar phase (MacDonald, 1986). However, seasonal, interannual, and geographic patterns of recruitment vary, which are determined to some extent by larval availability resulting from oceanographic conditions such as the strength of the subtropical counter current (MacDonald, 1986; Mitchum and Polovina, 1992; Polovina and Mitchum, 1994; Polovina and Moffitt, 1995; Polovina *et al.,* 1999).

Pueruli settle in depths between 1 and 30 m, and at low densities relative to other spiny lobster species (MacDonald, 1989; Polovina and Moffitt, 1995). While other *Panulirus* sp. use shallow nearshore algal, seagrass, and mangrove roots as nurseries, these types of habitats are poorly represented in Hawaii (MacDonald and Stimson, 1980). In the NWHI, there was no correlation found between shallow habitat and fishery production, suggesting that lobster pueruli may recruit directly to deeper waters from the pelagic habitat relative to other tropical lobster species (Parrish and Polovina, 1994). Upon settling, puerulus molts into the postpuerulus stage, typically around the time of the full moon (Macdonald, 1986).

1.3.4. JUVENILE STAGE

Although post-larval recruitment is influenced by the abundance of pueruli in the banks surrounding waters, differences in adult production between banks in the NWHI is also driven by availability of juvenile habitat (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The habitat requirements of juvenile spiny lobsters are believed to be the bottleneck for adult lobster abundance (Parrish and Polovina, 1994). Observations of small lobsters between 1 and 30 m provide evidence that 30 m is the deepest that lobster larvae are able to settle (Polovina and Moffit, 1995). The highest abundances of juveniles are found in benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994). Lower densities of juvenile lobster are found in habitats with low vertical relief (< 5 cm) and high vertical relief (>30 cm) (Parrish and Polovina, 1994). Intermediate vertical relief is provided by scattered coral colonies and algal fields, which are common habitats in the 2 most historically productive fishing grounds at Necker Island and Maro Reef (Parrish and Polovina, 1994). The intermediate vertical relief benthic habitat likely represents a compromise between shelter and abundance of predators; it is enough relief to provide some shelter, but in habitats with relief > 30 cm predatory reef fish such as sharks and jacks that prey on juvenile lobsters are more abundant.

Not only do benthic algae provide shelter, it may also play a role in the trophic ecology of lobsters (MacDiarmid *et al.,* 1991). Macroalgae that provide intermediate vertical relief found in the NWHI include *Dictopterus* sp., *Sargassum* sp., and *Padina* sp. Algal presence and growth is closely associated with temperature, thus northerly banks may be more susceptible to cooling and loss of algae cover resulting in reduced recruitment, increased natural predation, and potentially a reduction in food available to lobsters (Parrish and Polovina, 1994).

1.3.5. ADULT STAGE

Adult lobsters recruit to the fishery approximately 3 years after settling on to benthic habitat, which is slightly larger than the onset of sexual maturity (MacDonald 1985; Polovina and Mitchum, 1992). Generally adult lobsters are found in depths between 20 and 150 m at banks with summits less than 30 m deep, and do not move between banks, which can have depths over 4,000 m (Parrish and Polovina, 1994; Polovina *et al.,* 1995). The depth with highest abundance of lobsters varies with latitude and is likely a result of temperature (Uchida and Tagami, 1984). In the southern portion of the NWHI highest abundances were found in depths from 37 and 64 m, but north of Gardener Pinnacles higher abundances were found in depths of 10 to 36 m. Commercial fishers frequently fish in depths between 20 and 70 m (Polovina, 1993).

Vertical relief of habitat is not found to be correlated with adult lobster abundance (Parrish and Polovina, 1994). Perhaps this is because adult lobsters are less vulnerable to predators (Parrish and Polovina, 1994). Adult lobsters are often found in cracks and crevices of reefs, have been observed moving across open sandy areas between reef patches in pairs (MacDonald 1984), and are also found on the banks of deep slopes that are characterized by 'heavy seas, strong bottom surge, and swift currents' (Parrish and Kazama, 1994).

Unlike other *Panulirus* sp., adult lobsters do not undergo significant migrations. Tag and recapture studies in the NWHI found that the majority of lobsters moved < 1 km after over a year at liberty (O'Malley and Walsh, 2013). Limited movement patterns are likely because juvenile and adult lobster habitats are the same, offshore currents are within reach of newly hatched larvae, and the NWHI do not experience large seasonal shifts in water temperature (O'Malley and Walsh 2013).

P. marginatus are nocturnal predators (FAO, 1991) and are regarded as omnivorous, opportunistic scavengers (Pitcher, 1993). Food items reported from the diets of *Panulirus sp*. include echinoderms, crustaceans, mollusks (primarily gastropods), algae, and seagrass (Pitcher 1993). Catchability of spiny lobsters does not appear to be related to seasonal or lunar changes (MacDonald and Stimson, 1980)

1.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	30-40 days (Morris,1968)	N/A	benthic (brooded by females)	N/A	N/A	N/A
Larvae (phyllosoma)	12 months (Polovina and Moffit, 1995)	N/A	80-100 m (daytime) 10- 20 m (night) (Polovina and Moffit, 1995).	Offshore (25 nmi from 200 nm contour) (Polovina and Moffit, 1995)	N/A	strength of the Subtropical Counter Current (SCC) at 26° N latitude and sea level height (Polovina, 1999)
Post-pueruli and Juvenile	~3 years (Polovina and Moffit, 1989)	N/A	1-30 m (Polovina and Moffit, 1995)	Settlement higher at center of Archipelago and in NWHI (MacDonald, 1986)	benthic habitat with intermediate (5-30 cm) vertical relief (Parrish and Polovina, 1994)	Temperature** (Polovina and Parrish, 1994)
Adult	Up to 20 years (Butler and MacDiarmid, 2011)*	echinoderms, crustaceans, mollusks, (primarily gastropods) algae, and seagrass (Pitcher, 1993)	between 20 and 150 m at banks with summits < 30 m deep (Polovina *et al.*, 1995)	Highest abundances in NWHI Maro Reef and Necker Island (Lacchei *et al.*, 2014)	Slopes of banks with rocky substrate or found in cracks and crevices in coral reef habitat (Polovina, 1989; Pitcher, 1993)	High abundance found in areas with heavy seas (4-6 ft.), strong bottom surge, and swift currents (1-2 knots) (Parrish and Kazama 1994) Also found in calm lagoon areas in the NWHI(Lacchei and Toonen, 2013)

*Based on other species of spiny lobster.
**Algal cover that provides intermediate relief habitat utilized by juveniles is impacted by temperature.

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2. RED SPINY LOBSTER (*PANULIRUS PENCILLATUS*)

2.1. SPECIES DESCRIPTION AND DISTRIBUTION

Panulirus pencillatus also known as the ula, red spiny lobster, and proghorn spiny lobsters, is found from the Indo-West to the Eastern Pacific, the widest known geographic distribution of any spiny lobster species (Cockcroft *et al.,* 2011). Two genetically distinct populations have been identified between the western/central and eastern Pacific (Abdullah *et al.,* 2014). The common name of the species comes from the body color of individuals found in the eastern Pacific, which is less fitting for *P. pencillatus* with a greenish body color that are found in the western/central Pacific (Abdullah *et al.,* 2014).

2.2. FISHERIES

Red spiny lobster is targeted by lobster fisheries throughout its range, and is considered overexploited in many regions (Cockcroft *et al.,* 2011). Due to its relatively shallow depth preference, it most typically is targeted using hands from spearfishers, or fishers who walk along the reef flat at night (Coutures, 2003). In the Western Pacific region, fisheries exist for the red spiny lobster in American Samoa, CNMI, Guam, and the MHI (McGinnis, 1972; Coutures, 2003; Porter *et al.,* 2005). It is the most abundant lobster species in American Samoa, one of the top landed invertebrate species in CNMI and has been heavily exploited in the MHI. Although not targeted in the NWHI lobster fishery, red spiny lobsters were landed in low numbers (DiNardo and Moffit, 2007).

2.3. LIFE HISTORY

2.3.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Like other lobster species, *P. pencillatus* growth is step-wise and body size increases by molting (Coutures, 2003). Reported growth rates vary substantially by region and are likely affected by local factors such as temperature and growth. Growth rates are generally high in juveniles and decrease with age, specifically at the onset of maturity, when more energy is devoted towards reproductive growth and molting becomes less frequent (Courtes, 2003).

P. pencillatus are sexually dimorphic, males reach larger sizes and grow faster than females (Coutures, 2003). Size at 50% sexual maturity in the Western Pacific region is estimated at 6 cm CL, approximately 2-3 years after settling in benthic habitat (Ebert and Ford, 1986; Coutures, 2003). The largest male is reported as 16 cm carapace length (Richer de Forges and Laboute, 1995).

Although natural mortality rates (*M*) vary with size and age, an average *M* of 0.25 per year was estimated for lobsters in CNMI (Ebert and Ford, 1986). Large males may be more vulnerable to predation due to difficulty finding large dens (Coutures, 2003). Large males may be absent on reefs where large dens are not available due to high predation rates. Although specific mortality rates have not been reported for this species, other spiny lobsters lived up to 20 years (Butler and MacDiarmid, 2011).

2.3.2. REPRODUCTION

Spawning season varies by location. For example, Enewetak Atoll in the Marianas has a peak in berried females during the spring, while the presence of berried females in another nearby atoll peaked in the fall (Ebert and Ford, 1986). In Hawaiʻi, berried females are found throughout the year (MacDonald, 1971). The drivers behind seasonality of spawning are not known, but may be related to environmental factors such as temperature (Ebert and Ford 1986).

The relationship between size and fecundity of females is exponential, and females may spawn 2-3 times per year (MacDonald, 1971; Pitcher, 1992). Like other spiny lobster species, fertilization is external and occurs when the male deposits a spermatophore on the abdomen of the female which she scratches off to fertilize extruded eggs. Eggs are brooded for approximately one month before hatching as pelagic larvae (Chubb, 1994). Females release eggs in areas that allow the pelagic larvae to quickly drift offshore (Coutures, 2000).

2.3.3. LARVAE AND RECRUITMENT

Phyllosoma larvae drift in the pelagic environment for up to 8-9 months before settling (Matsuda *et al.,* 2006) where they are carried up to 3,700 km by ocean currents and gyres (Johnson, 1974). In larval tows across the Hawaiian archipelago, *P. pencillatus* phyllosoma were found in high abundance near Oʻahu, but were not present in any tows east of French Frigate or off of Midway Atoll (Johnson, 1968).

Limited information is available about *P. pencillatus* recruitment in the Western Pacific region, but they are believed to settle in the same benthic habitat utilized by adults, near the outer reef break (Coutures, 2003). In French Polynesia, *P. pencillatus* post-larvae make active settlement choices, with highest preference towards dead coral (Lecchini *et al.,* 2010). Recruitment also occurred on live coral, macroalgae, and sand (Lecchini *et al.,* 2010).

2.3.4. JUVENILE STAGE

No juvenile specific information was found in the literature, but they are thought to inhabit the same areas as adult lobster (Coutures, 2003).

2.3.5. ADULT STAGE

Red spiny lobsters occupy relatively shallow depths from 1-16 m deep on small islands or near arid coasts (Holthuis, 1991). In the Western Pacific adults are found in clear waters near fringing or reefs slopes that are exposed to high wave energy, habitat that is typically found on the windward exposure of islands in depths up to 5 m (George, 1992; Ebert and Ford, 1986). *P. pencillatus* are nocturnal, hiding in protected caves and corals, or under boulders during the day that are present in lagoons and the outer reef slope (George, 1972; MacDonald, 1979; Coutures, 2003). At night, lobster move up the spurs and grooves of surge channels at the reefs edge and into shallow reef flats to forage (Coutures, 2003).

P. pencillatus have a robust pereiopod, which may be an advantageous adaption that allows foraging in shallow, high energy wave environments where rates of foraging competition and predation may be lower (MacDonald, 1988). Spiny lobster feed on algae, crustaceans, echinoderms, polychaets, and mollusks found in reef flats (Graham, 1993). Females migrate further up the reef flat (closer to shore) than males at night, which may make them more susceptible to fishers walking on reef flats (Ebert and Ford, 1986).

In Hawaii, historical exploitation rates are higher in the MHI than in the NWHI due to the >18 m depth restriction that was used to manage the NWHI lobster fishery (Lacchei *et al.,* 2014). However, in general, abundances of spiny lobster are much higher in the MHI compared to the NWHI because of the larger area of available shallow habitat (Lacchei *et al.,* 2014). In Tutuila, American Samoa the total area of *P. pencillatus* habitat is small, a narrow ban that has a 20-25 m width around the reef edge. In CNMI the estimated density of lobsters per linear km is on average 126 (Ebert and Ford, 1986).

2.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	1 month (Chubb, 2000)	N/A	Benthic (brooded by females)	N/A	N/A	Eggs hatched in areas accessible to currents (Coutures, 2003)
Larvae	8-9 months (Matsuda *et al.*, 2006)	N/A	Pelagic	Offshore	N/A (pelagic)	Oceanic gyres and currents (Johnson, 1997)
Juvenile	2-3 years (Ebert and Ford, 1986)	N/A	N/A	N/A	Dead coral, live coral, macroalgae, sand (Lecchini *et al.*, 2010)	N/A
Adult	Up to 20 years (Butler and MacDiarmid, 2011)*	Algae, crustaceans, echinoderms, polychaetes, mollusks (Hothuis, 1991)	0-5 m (George, 1972)	Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Coutures, 2003)	Reef or rocky areas with high vertical structure (Coutues, 2003)	Clear oceanic waters and high energy wave action typical of windward exposure (Holthuis, 1991)

*Based on other species of spiny lobster.

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3. SLIPPER LOBSTER (*SCYLLARIDES SQUAMOSUS*)

3.1. SPECIES DESCRIPTION AND FISHERIES

The scaly slipper lobster (*Scyllarides squamosus*), or ulu papapa, is found throughout the Indo-Pacific from east Africa to Japan, Hawai‘i, Melanesia, and Australia (Butler *et al.,* 2011). In the NWHI *S. squamosus* is assumed to make up a single meta-population (DiNardo and Moffit, 2007).

S. squamosus made up a minor portion of catch in the NWHI from the 1970s to 1996 in fishers primarily targeting *P. marginatus*. From 1997-1999 several commercial vessels began targeting slipper lobster at Maro Reef (DeMartini and Kleiber, 1998), During the time that the NWHI lobster fishery was active, because little was known about the life history of the scaly slipper lobster, life history parameters were borrowed from the spiny lobster species that was also targeted in the fishery (O’Malley, 2011). However, recent studies on *S. squamosus* reveal life history characteristics between the two species are very different than previously thought (O’Malley, 2011). The NWHI was closed in 2000 due to uncertainty in assessment results and population status of both lobster species. Recent fishery independent surveys indicate that abundance of scaly slipper lobsters has not increased since that time (O’Malley, 2011).

In the MHI, the slipper lobster is managed with 7 cm tail width minimum size regulations.

3.2. LIFE HISTORY

3.2.1. GROWTH, MATURITY, NATURAL MORTALITY, AND MOVEMENT

Growth of *S. squammosus* varies by location. Growth is best described by the Schnute model; juveniles experience faster growth rates, which decline with the onset of maturity (O’Malley, 2011). In the NWHI, growth rates vary by bank; however, individual variation in growth at each bank is minimal (O’Malley, 2011).

Size at sexual maturity also varies by location, but has been reported occurring around 6.6-6.7 cm (Hearn *et al.,* 2007, Lavalli *et al.,* 2009). Adults can reach sizes up to 20 cm CL (Holthuis, 1991). Natural mortality varies by location and year (O’Malley, 2009), and adults do not move large distances (< 1 km; O’Malley and Walsh, 2013).

3.2.2. REPRODUCTION

In Hawai‘i, ovigerous females are found throughout the year and peak in abundance during May and July when water is warmer (O’Malley 2011). Fecundity increases with size and ranges between 54,000 and 227,000 eggs per female (DeMartini and Williams, 2001; DiNardo and Moffitt 2007; Sekiguchi *et al.,* 2007).

3.2.3. LARVAE AND RECRUITMENT

The pelagic larvae duration of *S. squamosus* is between 3 - 6 months (DiNardo and Moffitt, 2007). Larvae have been found up to 20 km of coast of southwest O‘ahu (Phillips and McWilliam, 1989) and in midwater trawls around the Marianas (Sekiguchi, 1990).

3.2.4. JUVENILE STAGE

There is no information on the juvenile stage of *S. squammosus*.

3.2.5. ADULT STAGE

S. squammosus are found in reefs and rocky areas (Holthuis, 1991). The reported depth range of this species varies by location. In Hawai‘i, the reported depth range is 30 – 120 m (DiNardo and Moffit, 2007). In other areas it is reported as 5-80 m with highest abundances at 20-50 m (Chan, 1998). Adult *S. squammosus* are found in very high densities in banks making them very vulnerable to trap fisheries (Clarke and Yoshimoto, 1990).

The scaly slipper lobster reaches sexual maturity between a 66-67 mm carapace length (DeMartinit and Kleiber, 1998) and can reach a maximum size of 15 cm carapace length (Holthuis, 1991) shelters during the day, and forages at night where it feeds mainly on bivalves (Chan, 1998; Lavalli and Spanier, 2007). Adults are known to feed on bivalves (Chan, 1998; Lavalli and Spanier, 2007).

3.3. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg			benthic (brooded by females)			
Larvae	3-6 month (DiNardo and Moffit, 2007)		pelagic	Offshore (at least 20 km) (Phillips and McWilliam, 1989)	N/A (pelagic)	Optimal temperature 25-29 C (Minagawa, 1990)
Juvenile						
Adult		Bivalves (Chan 1998, Lavalli *et al.,* 2007)	1-120 m (DiNardo and Moffit, 2007)	Most common on outer reef slopes of fringing reefs moving at night up surge channels at the reef edge and onto shallow reef flats (Courtes, 2003)	Reef and rocky areas (Holthuis, 1991)	

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4. KONA CRAB (*RANINA RANINA*)

4.1. GENERAL SPECIES DESCRIPTION AND DISTRIBUTION

The kona crab (*Ranina ranina*), also known as frog crab, red frog crab, papa'i kua loa, krab ziraf, and spanner crab is a large marine brachyuran which is targeted by both commercial and recreational fishers in Hawai'i. While Hawai'i represents the easternmost point of the Kona crab's range (Brown, 1985) commercial fisheries also exist in Australia, Japan, Philippines, Thailand, Seychelles Islands and Hawai'i (Brown, 1985; Tahil, 1983; Boulle, 1995; Krajangdara and Watanabe, 2005). The largest fishery for Kona crabs is found in Queensland, Australia where annual landings can reach over six million pounds making it the largest single species fishery in the State (Dichmont and Brown, 2010). No genetic information is currently available to determine the connectivity of Kona crabs across the Hawaiian Archipelago.

4.2. FISHERIES

A small commercial fishery for Kona crabs has operated continuously in the MHI since 1938, with an annual peak in landings of 70,000 lbs. occurred in 1972 (Vansant 1978). Additionally, a small number of crabs were landed in the NWHI and Kona crab were taken incidentally in the NWHI spiny lobster fishery (closed in 2000) (Brown 1985). Historically, the majority of Kona crab landings in Hawai'i have come from either Penguin Bank, located off the southwest coast of Moloka'i, or from the northwest coast of Ni'ihau (Onizuka, 1972). Several fishermen also operate off the north coast of O'ahu (Onizuka, 1972). Kona crab is thought to be a popular target for recreational fishers (Smith, 1993) however, the extent of the recreational fishery is not known.

Currently the State of Hawai'i Department of Aquatic Resources (HDAR) manages the MHI Kona crab stock as one management unit. The fishery is currently managed using four regulations: (1) seasonal closure May-August, (2) a minimum legal size of 4 inch carapace length, (3) no taking/killing of female crabs and (4) no spearing of crabs. The same regulations apply to recreational fishers. The WPRFMC does not have species-specific management measures applicable to federal waters.

4.3. LIFE HISTORY

4.3.1. GROWTH, MATURITY, MOVEMENT, AND NATURAL MORTALITY

Definitive growth rates of Kona crabs are not known but some partial information is available. In Australia two opposing hypotheses for the growth rates of Kona crabs have been proposed. The fast growth hypothesis estimates that crabs will reach a minimum legal size (4 inches) within 18 months will be 5.5 inches in 4 years and will attain maximum size within 8 to 9 years (Brown, 1986; Boullé, 1995). The slow growth hypothesis estimates that male crabs would take 4 years to reach minimum legal size (4 inches), nine years to attain 5.51-inch size and 14 - 15 years to attain maximum size found in this species (de Moussac, 1988; Chen and Kennelly, 1999; Brown *et al.,* 1999; Kirkwood *et al.,* 2005). Aquarium-reared Kona crabs were found to grow approximately 0.25 inches per week from the time they settle, until the time they have reached the ninth instar (Brown *et al.,* 2008).

The growth rates of Kona crabs are difficult to assess as their hard parts are lost during molting, and growth rates are stepwise between molts (Brown *et al.,* 1999). Catch and recapture methods to determine growth provide an overestimation of time between molts as time since last molt of recaptured crabs cannot be determined (Chen and Kennelly, 1999) and tagging can negatively affect growth rates (Brown *et al.,* 1999). An attempt at analyzing lipofuscin in the brain and eyestalks of the crabs to determine age was unsuccessful (Brown *et al.,* 2008) although this technique has been successful in other crustaceans (Sheehy and Prior, 2008). Due to high mortality rates of Kona crabs in captivity future attempts using this technique must begin with a larger sample size (Brown *et al.,* 2008). Overall, male Kona crabs grow faster than females and grow more per molt (Chen and Kennelly 1999; Brown *et al.,* 1999). Smaller crabs molt much more often than larger crabs. However, larger crabs experience more growth per molt (Chen and Kennelly, 1999). In Hawaiʻi males grow on average 0.39 inches per molt and females grown an average of 0.30 inches per molt (Onizuka, 1972). The growth rates found in Kona crabs vary by region, as is typical for many crustaceans (Kruse, 1993). Factors such as temperature and food availability are correlated with the number of molts a crab experiences and how quickly a crab is able to grow (Brown *et al.,* 1999).

The size at which Kona crabs reach sexual maturity varies by region and sex. Color of Kona crabs may be a general indicator of their sexual maturity; immature crabs are white and turn orange as they mature (Fielding and Haley, 1976). In Hawaiʻi, the majority of males were found to have mature spermatozoa at a 2.9 inch carapace length (Fielding and Haley, 1976). In Hawaiʻi, over 87% of females were sexually mature with a 2.6 inch carapace length (Onizuka, 1972).

Natural mortality rates for Kona crabs in Hawaiʻi are unknown (Onizuka, 1972). A preliminary estimate of natural mortality using the length converted catch curve was completed in the Seychelles Islands in the Indian Ocean. Natural mortality rates (M) in the Seychelles were estimated to be 0.8-0.9 yr^{-1} for female crabs and 1.0 yr^{-1} for males (de Moussac, 1988).

4.3.2. REPRODUCTION

Berried females (i.e., crabs that are bearing eggs) are found from May through September (Onizuka, 1972). The highest frequency of egg bearing females occurs in June and July. Ovarian growth for female Kona crabs occurs from February to May resulting in increased feeding during these months (Fielding and Haley, 1976). Feeding rates and thus emergence time in females has been found to be greatly correlated with their reproduction cycle (Kennelly and Watkins, 1994). Berried females rarely emerge from the sand causing catch rates for females to drop dramatically during certain times of the year (Skinner and Hill, 1987; Kennelly and Watkins, 1994). In months prior to breeding, emergence of females increases, as they search for food (Skinner and Hill, 1986).

In Kona crabs fertilization is external (Onizuka, 1972). Large brachyuran male crabs may be able to fertilize multiple females (Kruse, 1993). However, small male crabs may not be all of a female's eggs. A unique characteristic of brachyuran crabs is the ability of females to store sperm in the abdominal receptacle and successfully fertilize their eggs up to two years after copulation (Kruse, 1993). Male Kona crabs must be large enough to dig female crabs out of the sand and copulate (Skinner and Hill, 1986; Minagawa, 1993). The eggs are orange in color until a few days before hatching, when they turn brown (Onizuka, 1972). Eggs are brooded until they hatch 24 to 35 days after being fertilized (Onizuka, 1972).

4.3.3. LARVAE AND RECRUITMENT

Newly settled Kona crabs have been observed in the shallow waters of the surf break on a beach in west Maui (Layne Nakagawa, pers. comm.). Kona crab larvae spend several weeks as planktonic larvae which is their primary mechanism for dispersal (Brown, 1985). The first molt, when the larvae develop into a zoea I stage, is typically 7-8 days after the larvae hatch (Fielding, 1974). Six to seven days later a second molt occurs and the larvae develop into the zoea II stage. Prey density greatly affects the time between molts and the growth of these larval crabs (Minagawa and Murano, 1993a). Larvae begin to settle on the bottom 5-6 weeks after they have hatched (Brown *et al.,* 2008). The newly settled crabs typically have around a 0.40 inch carapace length (Brown *et al.,* 2008). The settlement cue for the larvae is unknown but they are presumed to settle in sandy substrata (Brown *et al.,* 2008). Larvae feed mostly during the day but little is known about the food preference of the larvae making aquaculture-rearing attempts unsuccessful to date (Minagawa and Murano, 1993b). Changes in temperature will affect the feeding habits of the larvae as water temperature is correlated with feeding rates (Minagawa and Murano, 1993b).

4.3.4. JUVENILE STAGE

The habitat of small juveniles is unknown but assumed to be similar to the adult habitat (Brown, 2001).

4.3.5. ADULT STAGE

Adult Kona crabs can reach up to 5.5-10.4 inches in length, and live up to 10 years (Pecl *et al.,* 2011). Adult Kona crabs are found in sandy substrata adjacent to coral reefs in areas subject to strong currents across the tropical and subtropical Indo-Pacific in depths ranging from 6 to 650 feet (Vansant, 1978). Most commercial Kona crab fishing in Hawaiʻi occurs from 50 to 150 feet (Vansant, 1978)

The crabs spend a majority of time buried in the sand to avoid predators which include sharks, rays, loggerhead turtles, large fish, and occasionally marine mammals (Skinner and Hill, 1986; Kennelly *et al.,* 1990). Kona crabs emerge from the sand to feed and mate (Skinner and Hill, 1986). Kona crabs are opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972).

4.4. SUMMARY OF HABITAT USE

Stage	Stage Duration	Diet	Depth Distribution	General Distribution	Benthic Habitat	Oceanographic Features
Egg	24-35 days (Onizuka, 1972)	N/A	benthic (brooded by females)	N/A	N/A	
Larvae	5-6 weeks (Brown *et al.*, 2008)		pelagic	Offshore	N/A (pelagic)	Temperature* (Minagawa and Murano, 1993b)
Juvenile		Similar to adults (Brown *et al.*, 2008)	Shallower than juveniles (pers. comm.)		Sandy substrata adjacent to coral reefs (Brown, 2008)	
Adult		Opportunistic scavengers but also feed on small fish and invertebrates (Onizuka, 1972)	2 – 200 m (Vansant, 1978)	Wide islands shelves (Thomas *et al.*, 2013)	Sandy substrata adjacent to coral reefs (smooth soft bottoms) (Brown, 2008)	Areas subject to strong currents (Vansant, 1978)

4.5. REFERENCES

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