ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION REPORT: PACIFIC REMOTE ISLAND AREA FISHERY ECOSYSTEM PLAN 2015

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The ANNUAL STOCK ASSESSMENT AND FISHERY EVALUATION (SAFE) REPORT for the PACIFIC REMOTE ISLAD AREA FISHERY ECOSYSTEM 2015 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, 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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The **Western Pacific Regional Fishery Management Council** acknowledges the valuable contributions of the following Plan Team members for drafting sections of this report:

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Executive Summary

As part of its 5 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: monitor the performance of the fishery and ecosystem, and maintain the structure of the FEP living document. The reports are comprised of three chapters: fishery performance, ecosystem considerations, and data integration. The 2015 Pacific Remote Island Area (PRIA) annual SAFE report does not contain the fishery performance or data integration chapter. The Council will iteratively improve the annual SAFE report as resources allow.

Ecosystem considerations were added to the annual SAFE report following the Council's review of its fishery ecosystem plans and revised management objectives (pending Secretarial transmittal). 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 and human dimensions sections will be included in later years as resources allow.

Fishery independent ecosystem survey data was acquired through visual surveys conducted in PRIA, American Samoa, Guam, Commonwealth of Northern Mariana Islands, Main Hawaiian Islands, and Northwest Hawaiian Islands. 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 PRIA are presented by sampling year and reef area. Finally, the reef fish population estimates for each PRIA study site are provided for hardbottom habitat (0-30 m).

The protected species section of this report summarizes information and monitors protected species interactions in fisheries managed under the PRIA FEP. There are currently no bottomfish, crustacean, coral reef or precious coral fisheries operating in the PRIA, and no historical observer data are available for fisheries under this FEP.

The 2015 Annual Report includes an inaugural section 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. 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, provide historical context and recognize patterns and trends. The atmospheric concentration of carbon dioxide (CO_2) trend is increasing exponentially with the 2015 time series maximum at 400.83 ppm. The oceanic pH at Station Aloha, in Hawaii, is decreasing at a rate of 0.039 pH units per year, equivalent to 0.4% increase in acidity per year. A strong El Niño was present with sea surface temperature (SST) in waters throughout the PRIA showing warm anomalies. SST in waters surrounding Palmyra ranged between 28.4 - 28.6º C while Howland and Baker ranged between 28.6 - 28.8º C; Wake Island between 27.5 - 28.0º C; and Johnston between 27.0 - 27.25º C with West Johnston being the warmest. The year also saw an abundance of tropical cyclones including 18 named storms and nine major hurricanes in the Eastern Pacific, 14 named storms and five major hurricanes in the Central Pacific, and 27 named storms in the Western Pacific. Wave forcing can have major implications for coastal ecosystems and pelagic fishing operations. Significant wave heights ranged between 1.5 - 1.8 m for Palmyra; 1.8 - 2.5 m for Howland and Baker; 1.8 - 2.1 m for Jarvis; 2.1 - 2.4 m for Wake; and 2.4 -2.7 m for Johnston.

The PRIA FEP and National Standard 2 guidelines require that this report include a report on the review of essential fish habitat (EFH) information. The 2015 annual report includes a draft update of the precious corals species descriptions. The guidelines also require a report on the condition of the habitat. In the 2015 annual report, mapping progress and benthic cover are included as indicators, pending development of habitat condition indicators for the PRIAs not otherwise represented in other sections of this report. The annual report also addresses any Council directives toward its plan team. Toward this end, a report on the HAPC Process is included as an attachment to the report.

The marine planning section of the annual 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. No ocean activities with multi-year planning horizons were identified for the Pacific Remote Islands Areas.

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ACRONYMS AND ABBREVIATIONS

ABC	Acceptable Biological Catch
ACL	Annual Catch Limits
AM	Accountability Measures
BiOp	Biological Opinion
BOEM	Bureau of Ocean Energy Management
BSIA	best scientific information available
CFR	Code of Federal Regulations
CMS	coastal and marine spatial
CNMI	Commonwealth of the Northern Mariana Islands
CPUE	Catch Per Unit Effort
CREMUS	Coral Reef Eco Management Unit Species
CREP	Coral Reef Ecosystem Program (PIFSC)
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EO	Executive Order
ESA	Endangered Species Act
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
HAPC	Habitat Area of Particular Concern
ITS	Incidental Take Statement
LOF	List of Fisheries
MFMT	Maximum Fishing Mortality Threshold
MHI	Main Hawaiian Islands
MMA	marine managed area
MPA	marine protected area
MPCC	Marine Planning and Climate Change

MPCCC	Council's MPCC Committee
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
MUS	management unit species
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NEPA	National Environmental and Policy Act
NMFS	National Marine Fisheries Service
NWHI	Northwestern Hawaiian Islands
OFL	Over-fishing Limit
OY	Optimum Yield
Pelagic FEP	Fishery Ecosystem Plan for the Pacific Pelagic Fisheries
PI	Pacific Islands
PIFSC	Pacific Islands Fisheries Science Center
PIRO	NOAA NMFS Pacific Islands Regional Office
PMUS	pelagic management unit species
RAMP	Reef Assessment and Monitoring Program (CREP)
ROA	Risk of Overfishing Analysis
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SDC	Status Determination Criteria
SEEM	Social, Ecological, Economic, and Management Uncertainty Analysis
TAC	Total Annual Catch
USACE	United States Army Corps of Engineers
WPRFMC	Western Pacific Regional Fishery Management Council

1 FISHERY PERFORMANCE

Fisheries in the Pacific Remote Island Area (PRIA) are limited. Fishery performance statistics will be made available for the PRIA in subsequent reports as resources allow.

2 ECOSYSTEM CONSIDERATIONS

2.1 Coral Reef Fish Ecosystem Parameters

2.1.1 Archipelagic 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 <30m hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only date from forereef habitats is used here. At each SPC, divers record the number, size and species of all fishes within or passing through paired 15m-diameter cylinders in 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 status, and has repeatedly been shown to be changes in fishing pressure, habitat quality, and oceanographic regime.

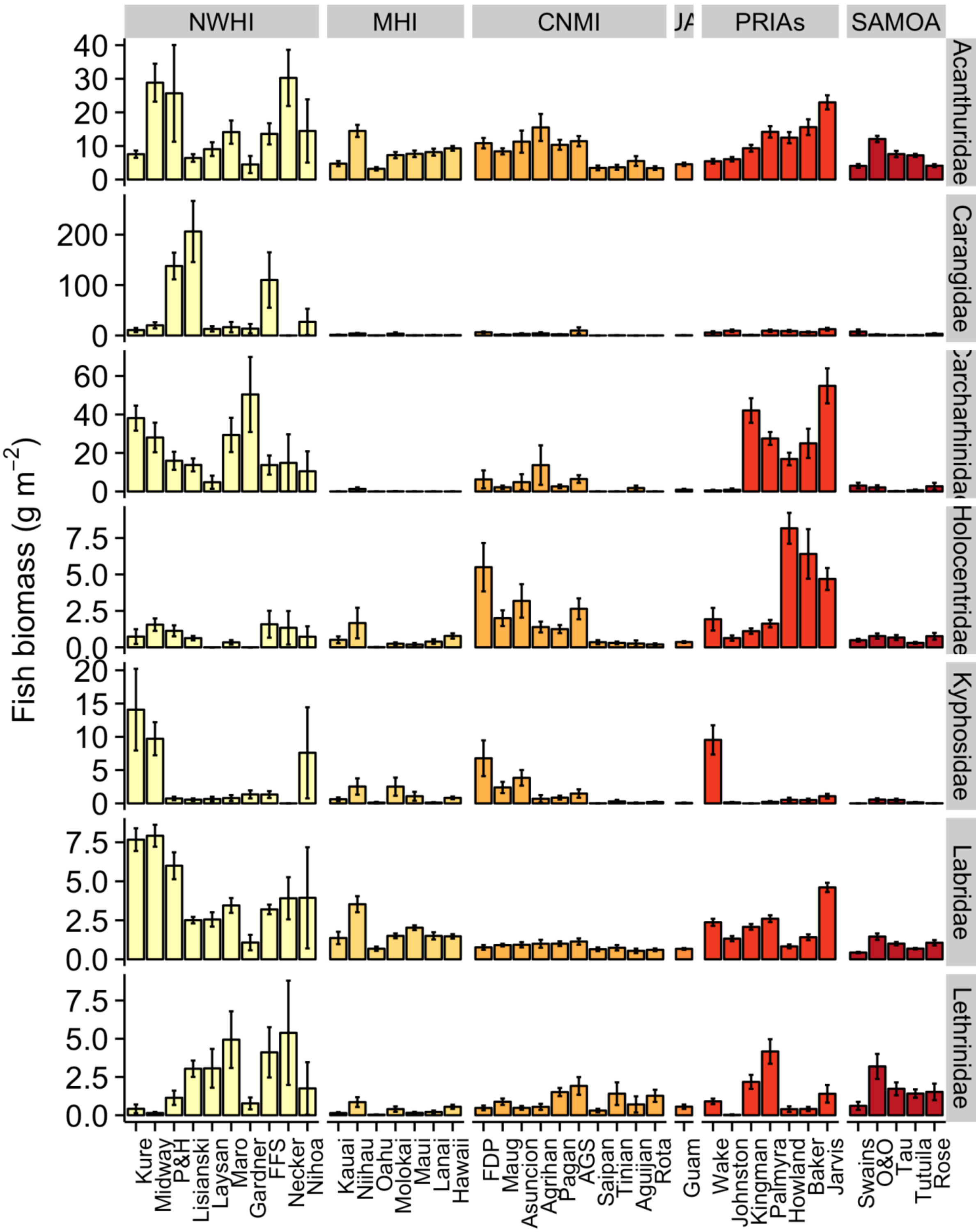
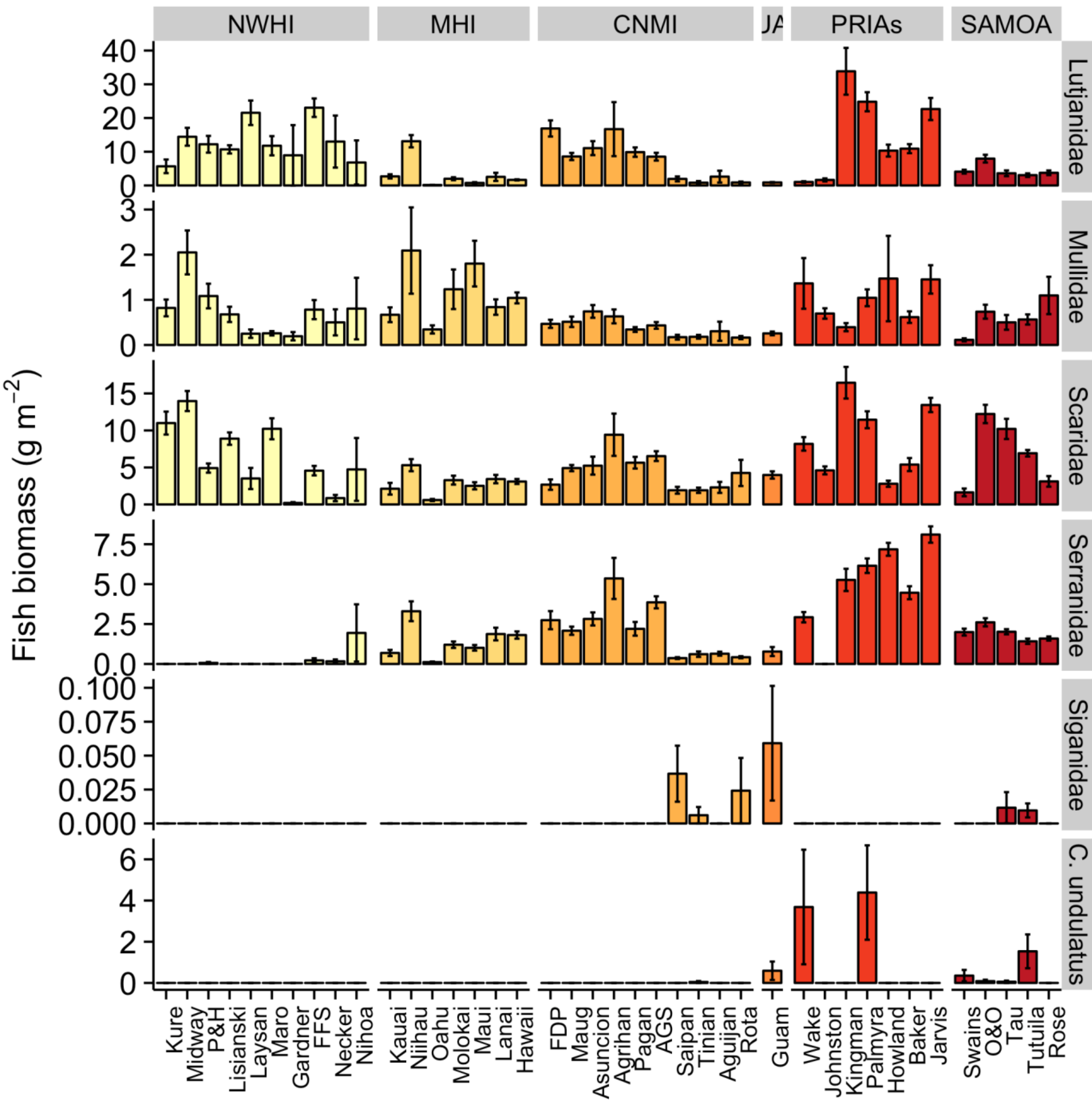


Figure 1. Mean fish biomass by Coral Reef Management Unit Species (CREMUS) grouping per US Pacific reef area. Mean fish biomass (± standard error) per CREMUS grouping per

reef area pooled across survey years (2009-2015). Islands ordered within region by latitude. Continues to 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 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

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 <30m hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only date from forereef habitats is used here. At each SPC, divers record the number, size and species of all fishes within or passing through paired 15m-diameter cylinders in 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 status, and has repeatedly been shown to be changes in fishing pressure, habitat quality, and oceanographic regime.

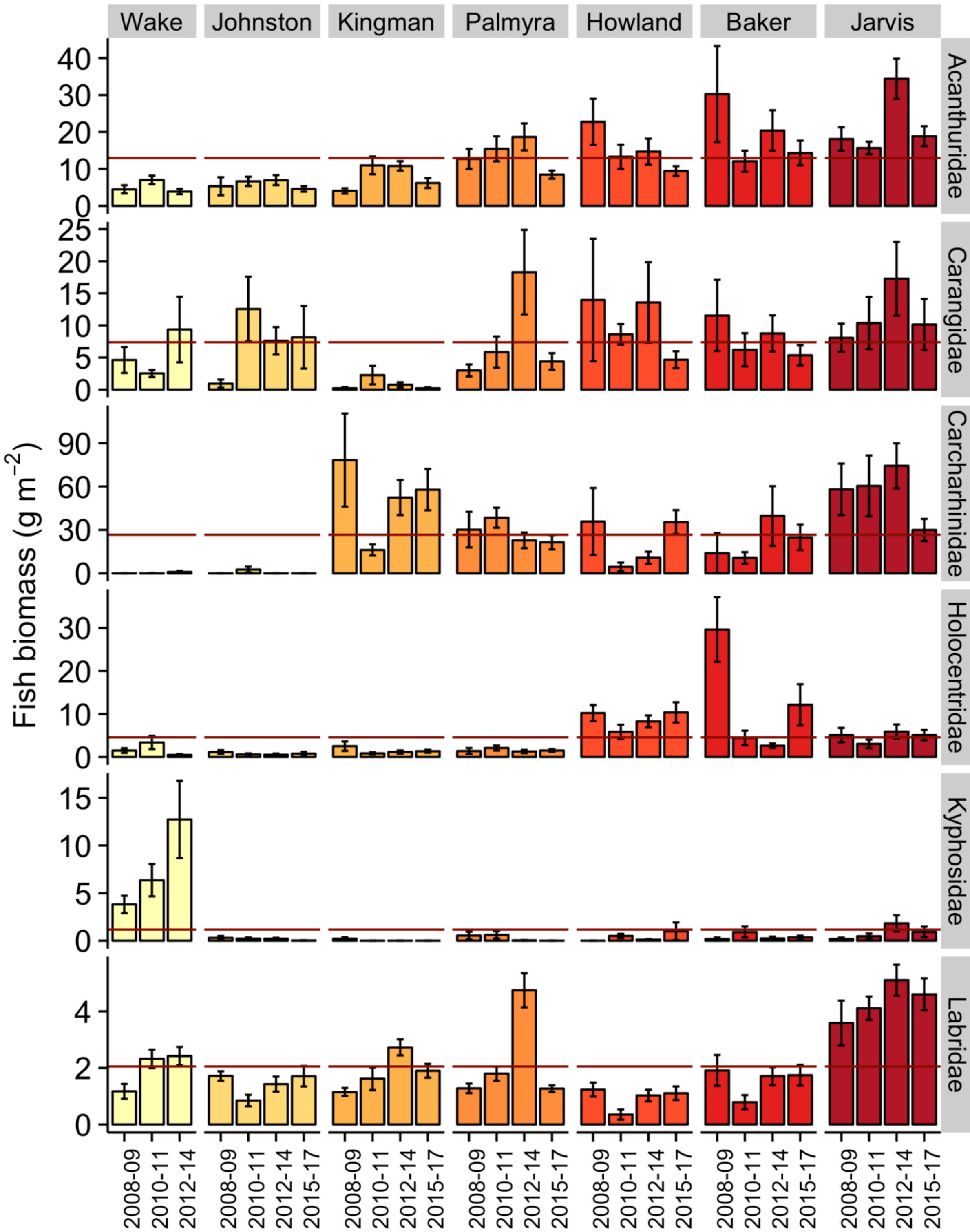
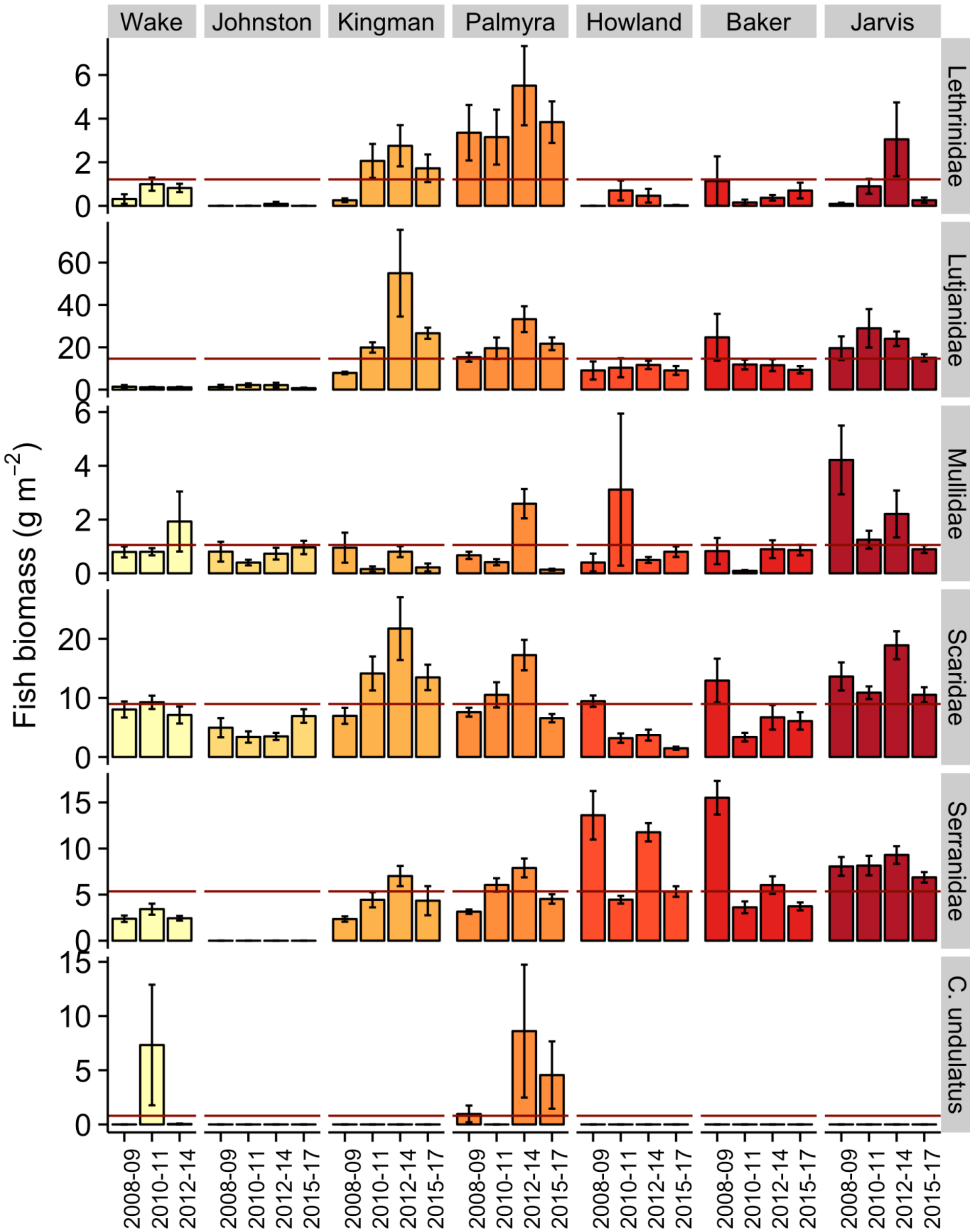


Figure 2. PRIA mean reef fish biomass. Continues to next page.



Wake
Johnston
Kingman
Palmyra
Howland
Baker
Jarvis
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
C. undulatus
Fish biomass (g m^{-2})
2008-09
2010-11
2012-14
2015-17

2.1.3 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 mean size 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 <30m hard-bottom habitat at each island, stratified by depth zone and, for larger islands, by section of coastline. For consistency among islands, only date from forereef habitats is used here. At each SPC, divers record the number, size (total length, TL) and species of all fishes within or passing through paired 15m-diameter cylinders in the course of a standard count procedure. 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. 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: Mean size is important as\mean size is widely used as an indicator of fishing pressure – not only do fishers sometimes preferentially target large individuals, but also because one effect of fishing is to reduce the number of fishes reaching older (and larger) size classes. Large fishes also 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.

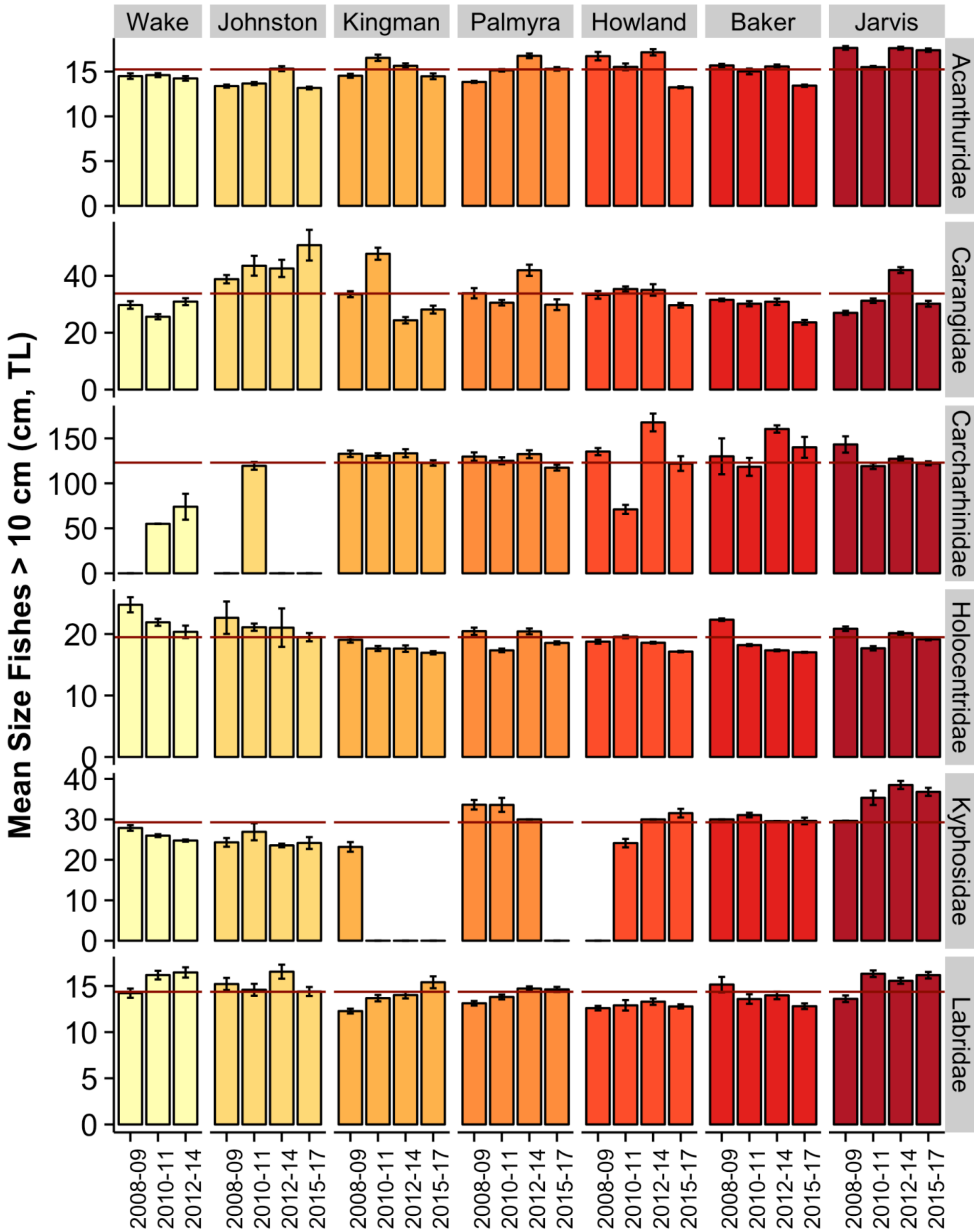
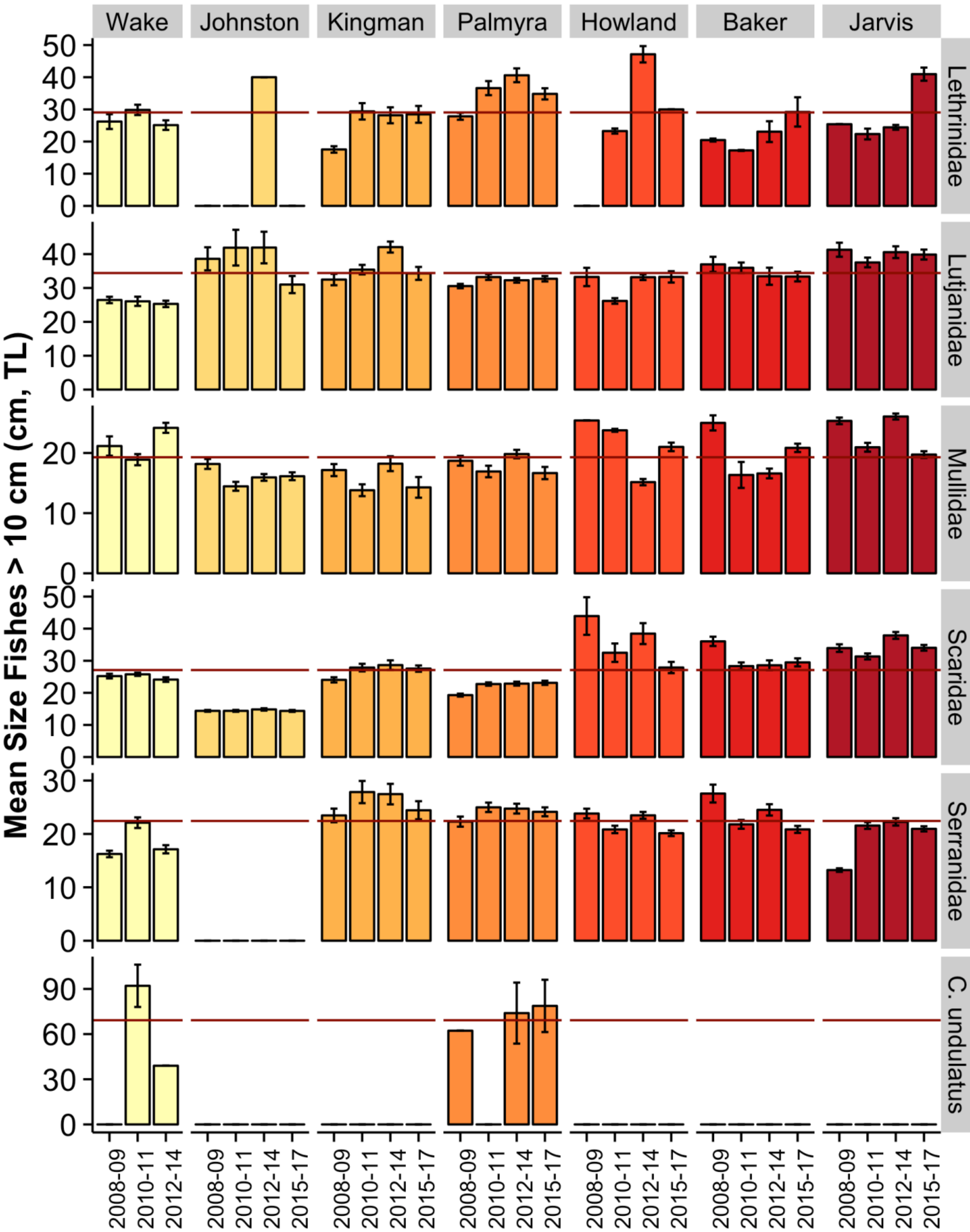


Figure 3. PRIA mean fish size. Continues to next page.



Wake
Johnston
Kingman
Palmyra
Howland
Baker
Jarvis
Lethrinidae
Lutjanidae
Mullidae
Scaridae
Serranidae
C. undulatus
Mean Size Fishes > 10 cm (cm, TL)
2008-09
2010-11
2012-14
2015-17

2.1.4 Reef Fish Population Estimates

Description: Reef fish population estimates are made by multiplying mean biomass per unit area by estimated area of hardbottom in a consistent habitat across all islands (specifically, the area of hardbottom forereef habitat in < 30m 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 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: REEF FISH BIOMASS). Those estimates are converted to population estimates by multiplying biomass (g/m2) per island by the estimated area of hardbottom habitat <30m deep at the island, which is the survey domain for the monitoring program that biomass data comes from.. Estimated habitat areas per island are derived from GIS bathymetry and habitat maps maintained by NOAA Coral Reef Ecosystems Program. It is important to recognize that many reef fishes taxa are present in other habitats and in deeper water than is surveyed by that program, and even that some taxa likely have the majority of their populations in deeper water. Additionally, fish counts have the potentiual to be biased by the nature of fish responses to divers- curious fishes, particularly in locations where divers are not perceived as a threat, will tend to be overcounted by visual survey, and skittish fishes will tend to be undercounted. Likely numbers of jacks and sharks in some locations (particularly the NWHI) are overcounted by visual survey. Nevertheless, in spite of these issues, the data shown here are consistently gathered across space and time.

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

Table 1. Reef fish population estimates for PRIA. Fish species are pooled by CREMUS groupings. Estimated population biomass is for 0-30 m hardbottom habitat only. (n) is number of sites surveyed per island. Each site is surveyed by means of 2-4 7.5 m diameter S SPCs -– however, those are not considered to be independent samples, so data from those is pooled to site level before other analysis.

			ESTIMATED POPULATION BIOMASS (metric Tonnes) in SURVEY DOMAIN OF <30m HARDBOTTOM					
ISLAND	Total Area of reef (Ha)	N	Acanthuridae	Carangidae	Carcharhinids	Holocentridae	Kyphosidae	Labridae
Wake	1,282.0	75	69.9	76.1	6.3	24.8	122.3	30.4
Johnston	9,410.2	104	570.1	887.6	81.2	60.1	13.5	124.7
Kingman	3,721.1	130	346.8	39.8	1,566.1	41.5	-	77.4
Palmyra	4,212.7	160	597.7	400.5	1,160.4	68.6	9.2	109.7
Howland	172.9	90	21.5	15.5	29.1	14.1	0.9	1.4
Baker	390.3	81	60.9	26.4	97.5	25.0	2.0	5.5
Jarvis	365.9	134	84.1	46.1	200.8	17.1	3.9	16.9
TOTAL	**19,555.1**	**774**	**1,754.9**	**1,490.6**	**3,217.0**	**249.3**	**111.2**	**363.0**
ISLAND	Total Area of reef (Ha)	N	Lethrinidae	Lutjanidae	Mullidae	Scaridae	Serranidae	*C. undulatus*
Wake	1,282.0	75	11.6	13.5	17.5	104.9	37.5	47.2
Johnston	9,410.2	104	2.9	155.1	65.6	433.2	-	-
Kingman	3,721.1	130	81.1	1,259.5	14.7	611.9	195.9	-
Palmyra	4,212.7	160	175.5	1,045.6	44.0	482.1	259.2	184.8
Howland	172.9	90	0.7	17.9	2.5	4.8	12.4	-
Baker	390.3	81	1.6	42.6	2.4	21.0	17.4	-
Jarvis	365.9	134	5.1	82.9	5.3	49.2	29.7	-
TOTAL	**19,555.1**	**774**	**280.1**	**2,661.1**	**148.8**	**1,707.2**	**549.1**	**220.8**

Note (1): No Siganidae or *Bolbometopon muricatum* were observed in PRIAs during these surveys.

2.2 Protected Species

This section of the report summarizes information on protected species interactions in fisheries managed under the PRIA FEP. Protected species covered in this report include sea turtles, seabirds, marine mammals, sharks and corals.

2.2.1 Indicators for Monitoring Protected Species Interactions in the PRIA FEP Fisheries

In this report, the Council monitors protected species interactions in the PRIA FEP fisheries using proxy indicators such as fishing effort and changes in gear types as these fisheries do not have observer coverage.

2.2.1.1 FEP Conservation Measures

Bottomfish, precious coral, coral reef and crustacean fisheries managed under this FEP have not had reported interactions with protected species, and no specific regulations are in place to mitigate protected species interactions. Destructive gear such as bottom trawls, bottom gillnets, explosives and poisons are prohibited under this FEP, and these provide benefit to protected species by preventing potential interactions with non-selective fishing gear.

2.2.1.2 ESA Consultations

ESA consultations were conducted by NMFS and the U.S. Fish and Wildlife Service (for species under their jurisdiction) to ensure ongoing fisheries operations managed under the PRIA FEP are not jeopardizing the continued existence of any listed species or adversely modifying critical habitat. The results of these consultations, conducted under section 7 of the ESA, are briefly described below.

Bottomfish Fishery

In a biological opinion issued on March 3, 2002, NMFS concluded that the ongoing operation of the Western Pacific Region's bottomfish and seamount fisheries is not likely to jeopardize the continued existence of five sea turtle species (loggerhead, leatherback, olive ridley, green and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei and sperm whales) (NMFS 2002a). NMFS also concluded in an informal consultation dated February 20, 2015 that fisheries managed under the PRIA FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark. NMFS also concluded on January 16, 2015 that fisheries managed under the PRIA FEP have no effects on ESA-listed reef-building corals.

Crustacean Fishery

An informal consultation completed by NMFS on September 28, 2007 concluded that PIRA crustacean fisheries are not likely to adversely affect five sea turtle species (loggerhead, leatherback, olive ridley, green and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei and sperm whales). NMFS also concluded in an informal consultation dated February 20, 2015 that fisheries managed under the PRIA FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark. NMFS also concluded on January 16, 2015 that fisheries managed under the PRIA FEP have no effects on ESA-listed reef-building corals.

Coral Reef Fishery

An informal consultation completed by NMFS on March 7, 2002 concluded that fishing activities conducted under the Coral Reef Ecosystems FMP are not likely to adversely affect five sea turtle species (loggerhead, leatherback, olive ridley, green and hawksbill turtles) and five marine mammal species (humpback, blue, fin, sei and sperm whales). NMFS also concluded in an informal consultation dated February 20, 2015 that fisheries managed under the PRIA FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark. NMFS also concluded on January 16, 2015 that fisheries managed under the PRIA FEP have no effects on ESA-listed reef-building corals.

Precious Coral Fishery

An informal consultation completed by NMFS on December 20, 2000 concluded that PRIA precious coral fisheries are not likely to adversely affect humpback whales, green turtles or hawksbill turtles. NMFS also concluded in an informal consultation dated February 20, 2015 that fisheries managed under the PRIA FEP are not likely to adversely affect the Indo-West Pacific DPS of scalloped hammerhead shark. NMFS also concluded on January 16, 2015 that fisheries managed under the PRIA FEP have no effects on ESA-listed reef-building corals.

2.2.1.3 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. PRIA fisheries are not classified under the LOF.

2.2.2 Status of Protected Species Interactions in the PRIA FEP Fisheries

There are currently no bottomfish, crustacean, coral reef or precious coral fisheries operating in the PRIA, and no historical observer data are available for fisheries under this FEP. No new fishing activity has been reported, and there is no other information to indicate that impacts to protected species from PRIA fisheries have changed in recent years.

2.2.3 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 non-commercial fisheries data to improve understanding of potential protected species impacts.
- Develop innovative approaches to derive robust estimates of protected species interactions in insular fisheries.
- Update analysis of fishing-gear related strandings of Hawaii green turtles.

2.3 Human Dimensions

Human habitation in the Pacific Remote Island Area is limited. Human dimensions data will be made available in subsequent reports as resources allow.

2.4 Climate and Oceanic Indicators

2.4.1 Introduction

The 2015 Annual Report includes an inaugural 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 the 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.

Beginning with the 2015 Report, the Council and its partners will provide 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.

2.4.2 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:

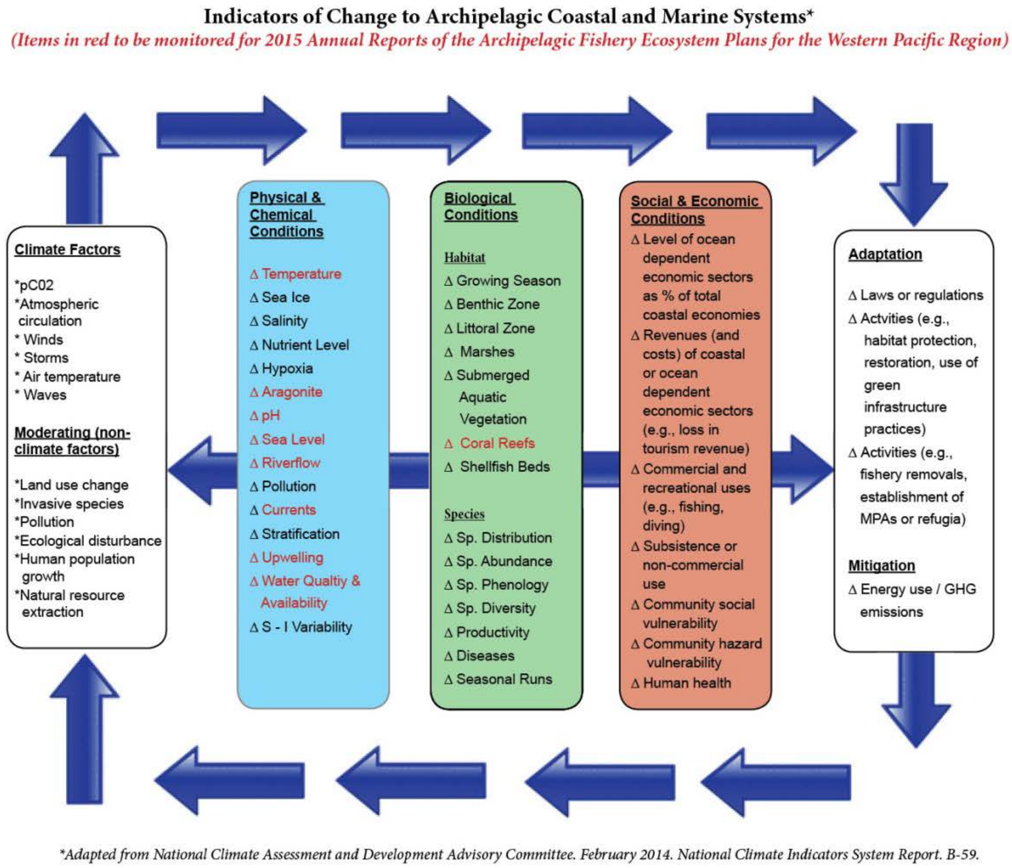


Figure 4. Indicators of change to archipelagic coastal and marine systems.

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 2.3. 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.

2.4.3 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 a 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.

For 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.

Sea Surface Temperature – Monthly sea surface temperature anomaly from 2003-2015 from the AVHRR instrument aboard the NOAA Polar Operational Environmental Satellite (POES). 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 is one of the most directly observable measures we have for tracking increasing ocean temperature.

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.

Heavy Weather (Tropical Cyclones) – Measures of tropical cyclone occurrence, strength, and energy. Tropical cyclones have the potential to significantly impact fishing operations.

Wave Data – To describe patterns in wave forcing, we present data from the Wave Watch 3 global wave model run by the Department of Ocean and Resources Engineering at the University of Hawai‘i in collaboration with NOAA/NCEP and NWS Honolulu. Wave forcing can have major implications for both coastal ecosystems and pelagic fishing operations.

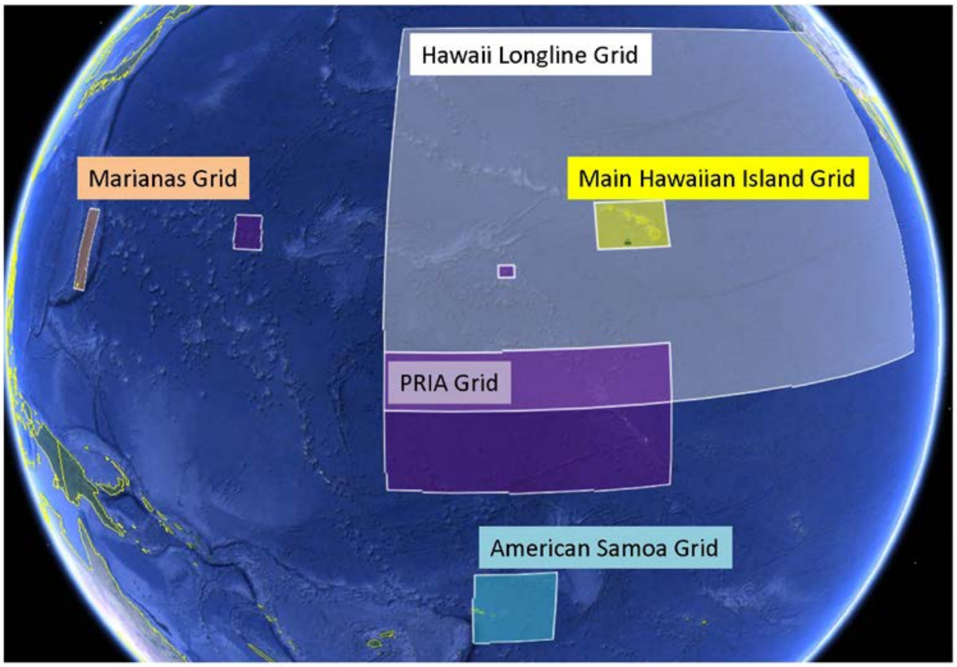


Figure 5. Regional Spatial Grids.

Table 2. PRIA climate and ocean indicator summary.

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 2015: time series maximum 400.83 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	2015: Strong El Niño

	patterns of key commercial fish stocks which in turn affect the location, safety, and costs of commercial fishing.	
Sea Surface Temperature[1] (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 Palmyra ranged between 28.4-28.6º while Howland and Baker ranged between 28.6-28.8º Wake Islands between 27.5-28.0ºC Johnston between 27.0-27.25ºC with West Johnston being the warmest Showing positive anomalies in all PRIA locations
Tropical Cyclones	Measures of tropical cyclone occurrence, strength, and energy. Tropical cyclones have the potential to significantly impact fishing operations.	Eastern Pacific, 2015: 18 named storms, time series maximum 9 major hurricanes Central Pacific, 2015: 14 named storms, time series maximum 5 major hurricanes Western Pacific, 2015: 27 named storms
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.	No tide gauge data for the Pacific Remote Island Area.
Wave Energy	WaveWatch III (WW3) Global Wave Model"run by UH Department of Ocean Resources & Engineering in collaboration with NOAA/NCEP & NOAA/NWS-Pacific Wave forcing can have major implications for both coastal ecosystems and pelagic fishing operations.	Significant wave heights ranged between 1.5-1.8m for Palmyra; 1.8-2.5m for Howland & Baker and 1.8-2.1m for Jarvis. Significant wave heights for Wake ranged from 2.1-2.4m and for Johnston 2.4-2.7m

2.4.3.1 Atmospheric Concentration of Carbon Dioxide (CO_2) at Mauna Loa.

Description: Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii in ppm from March 1958 to present. The carbon dioxide data is measured as the mole fraction in dry air, on Mauna Loa, A dry mole fraction is defined as the number of molecules of carbon dioxide divided by the number of molecules of dry air multiplied by one million (ppm). This

[1] 2015 data are incomplete.

constitutes the longest record of direct measurements of CO_2 in the atmosphere. The measurements were started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration [Keeling, 1976]. NOAA started its own CO_2 measurements in May of 1974, and they have run in parallel with those made by Scripps since then [Thoning, 1989].

The observed increase in monthly average carbon dioxide data is due primarily to CO_2 emissions from fossil fuel burning. CO_2 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, Hawaii are due to the seasonal imbalance between the photosynthesis and respiration of plants on land. During the summer 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 the presence of the continents. The difference between Mauna Loa and the South Pole has increased over time as the global rate of fossil fuel burning, most of which takes place in the northern hemisphere, has accelerated.

Timeframe: Yearly (by month)

Region/Location: Hawaii but representative of global concentration of carbon dioxide.

Data Source: "Full Mauna Loa CO_2 record" at http://www.esrl.noaa.gov/gmd/ccgg/trends/, NOAA ESRL Global Monitoring Division. The National Oceanic and Atmospheric Administration (NOAA) Global Monitoring Division provides high-precision measurements of the abundance and distribution of long-lived greenhouse gases that are used to calculate global average concentrations.

Measurement Platform: In-situ Station

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, the warming influence) of greenhouse gases in the atmosphere has increased substantially over the last several decades. In 2015, the annual mean concentration of C02 was 400.83 ppm. In 1959, the onset year it was 315.97ppm. It passed 350ppm in 1988.

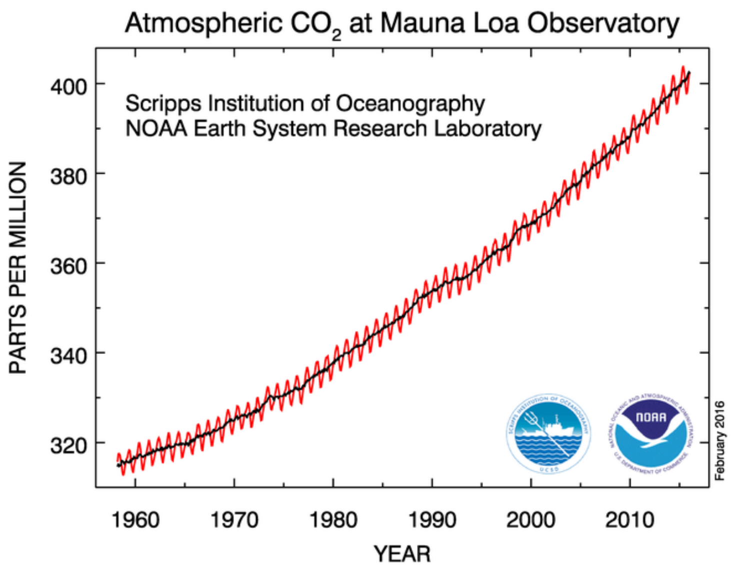


Figure 6. Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii. The carbon dioxide data (red curve), measured as the mole fraction (ppm). in dry air, on Mauna Loa. The black curve represents the seasonally corrected data.

2.4.3.2 Ocean pH

Description: Trends in surface (0-10m) pH and pCO2 at Station ALOHA, North of Oahu (22° 45' N, 158° W), collected by the Hawai'i Ocean Time-series (HOT). Green dots represent directly measured pH; blue dots represent pH calculated from total alkalinity (TA) and dissolved inorganic carbon (DIC).

The 25+ year time-series at Station ALOHA represents the best available documentation of the significant downward trend of ocean pH since 1989. Actual ocean pH varies in both time and space, but over the last 25 years, the HOTS Station ALOHA time series has shown a significant linear decrease of -0.0386 pH units, or roughly a 9% increase in acidity ([H+]) over that period.

Timeframe: Updated Monthly

Region/Location: North Oahu.

Data Source/Responsible Party: Hawai'i Ocean Time Series. (http://hahana.soest.hawaii.edu/hot/)

Measurement Platform: Oceanographic research station, shipboard collection.

Rationale: Increasing ocean acidification affects coral reef growth and health which in turn affects the health of coral reef ecosystems and the ecosystems and resources that they sustain. Monitoring pH on a continuous basis provides a foundation for documenting, understanding and, ultimately, predicting the effects of ocean acidification.

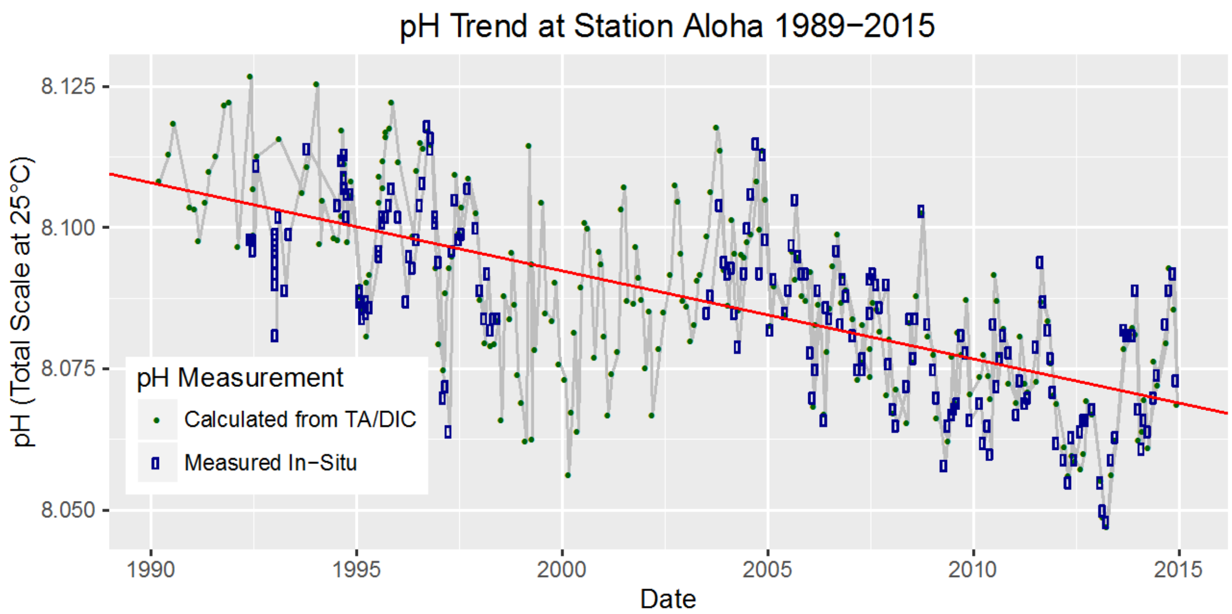


Figure 7. pH trend at Station Aloha 1989-2015.

2.4.3.3 Oceanic Niño Index (ONI)

Description: Warm (red) and cold (blue) periods based on a threshold of +/- 0.5°C for the Oceanic Niño Index (ONI) [three-month running mean of ERSST.v4 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°- 170°W)], based on centered 30-year base periods updated every five years.

For historical purposes, periods of below- and above-normal sea surface temperatures (SSTs) are colored in blue and red when the threshold is met for a minimum of five consecutive overlapping seasons. The ONI is one measure of the El Niño-Southern Oscillation, and other indices can confirm whether features consistent with a coupled ocean-atmosphere phenomenon accompanied these periods.

Description was inserted from:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Timeframe: Every three months.

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

Data Source/Responsible Party: NOAA NCEI Equatorial Pacific Sea Surface Temperatures (www.ncdc.noaa.gov/teleconnections/enso/indicators/sst.php)

Measurement Platform: In-situ Station, Satellite, Model, Other…

Rationale: The ONI focuses on ocean temperature which has the most direct effect on those fisheries. The atmospheric half of this Pacific basin oscillation is measured using the Southern Oscillation Index.

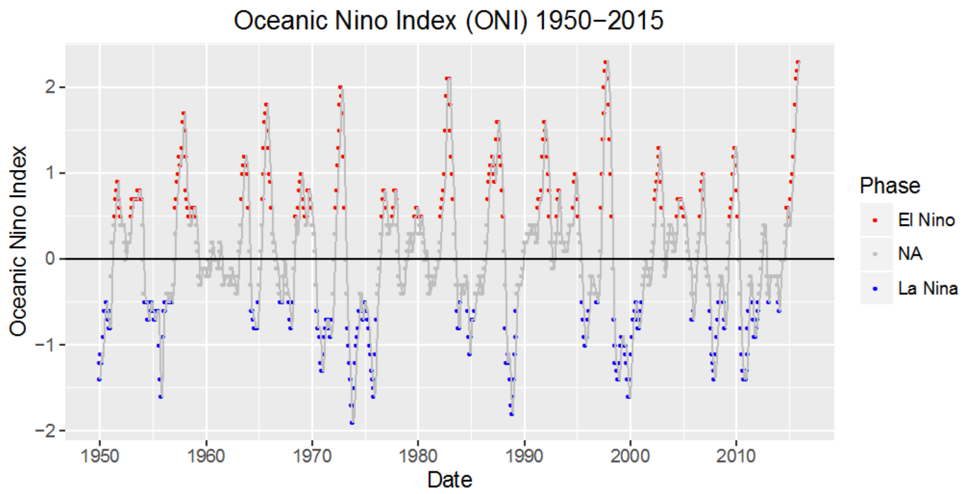


Figure 8. Oceanic Niño Index (ONI) 1950-2015.

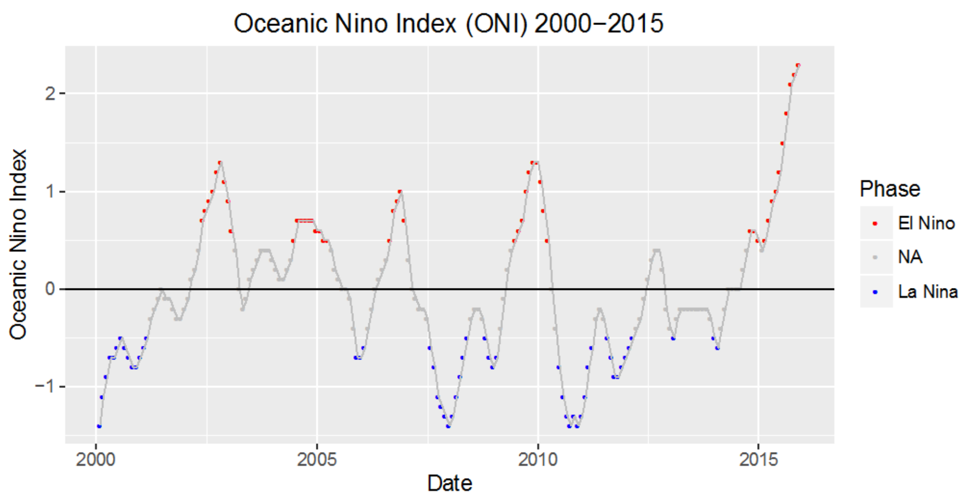
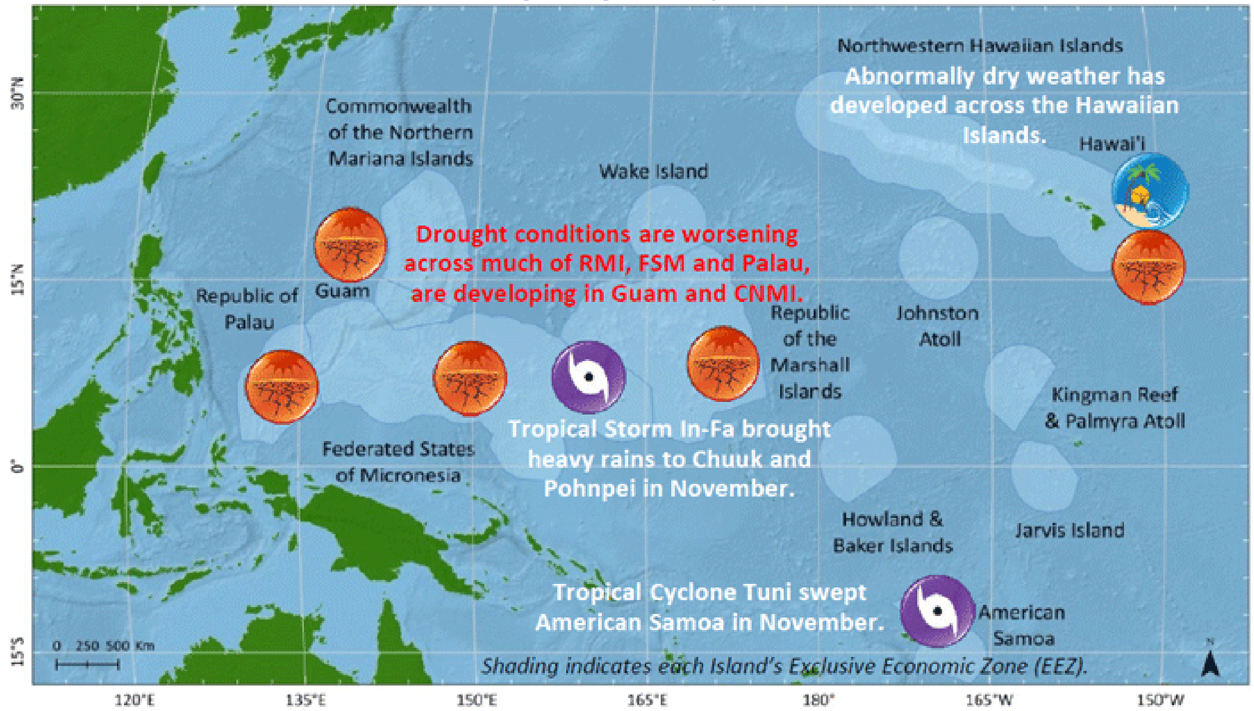


Figure 9. Oceanic Niño Index (ONI) 2000-2015.

The 2015-2016 El Niño

From: http://www.pacificcis.org/dashboard



Significant Events and Archipelagic Impacts

Facilities and Infrastructure – Significant surf-induced coastal flooding occurred on the north shore of Oahu in late January from 40' waves. The swell was enough to wash over Kam Highway, sending onlookers into the sea. In American Samoa, tropical cyclone Tuni resulted in flooding which closed much of the main road around the Independent Samoa island of Upolu.

Water Resources – The water storage reservoir on Majuro, RMI was 60% full as of 1 February, but household water tanks were critically low and some have gone dry. **As a result, the RMI Government has declared a State of Emergency,** activating the emergency operations center and mobilizing additional resources. Meanwhile, CNMI and Guam are being advised to begin water conservation measures as drought sets in. Residents on the islands of Palau, Yap, Chuuk, and the Marshalls are encouraged to check their water wells for excessive salinity as drought intensifies across the region.

Agriculture – Significant yellowing of food crops and vegetation have been observed in Guam, CNMI, Palau, and Yap, along with an increase in grass fires due to severe drought conditions. Yellowing of breadfruit tree leaves and pandanus fronds have been observed in Majuro.

Natural Resources **– Coral bleaching HotSpots are concentrated on the central equatorial Pacific Ocean but have diminished throughout most of the northeastern Pacific Ocean. Taimasa (low stands) conditions have been reported in American Samoa.**

Public Health – Drought is causing school attendance rates to drop across the Pacific Islands as hungry and dehydrated children face a high risk of malnutrition due to crop failure, water shortages, and poor sanitation.

The current El Niño has reached its peak and a slow decline towards neutral conditions is expected to begin in the 1st quarter 2016. However, many islands will continue to feel the effects of El Niño throughout much of 2016. The SST anomaly outlook for the 1st quarter indicates near-normal values in American Samoa, with slightly below normal values across CNMI, FSM, and Palau. Above-normal SST anomalies are forecast to continue across the Hawaiian Islands. The four-month coral bleaching outlook projects continued thermal stress to last through at least the end of May across the central equatorial Pacific. Alert Level 2 is expected to be widespread in the Eastern Pacific while the southwestern Pacific around the Great Barrier Reef, Vanuatu, and Fij, reaches Alert Level 1.

The forecast values for sea level in the 1st quarter indicate that most of the USAPI stations are likely to be much closer to normal. American Samoa is expected to be marginally below normal, with further falls expected as the year continues. In Hawaii, both Honolulu and Hilo are likely to be slightly elevated. Severe drought is expected to develop and/or continue across nearly all of the USAPI, including Palau, Yap, Chuuk, Pohnpei, and Kosrae, as well as all islands in the RMI, Guam and CNMI, and the Hawaiian Islands. Below-normal rainfall is projected for American Samoa. Tropical cyclone (TC) activity in the western north Pacific is expected to be quiet in the first quarter. During the last major El Niño event in 1998, Feb-Apr saw zero typhoons or tropical storms. In the southwest Pacific, due to strong El Niño conditions, the chances for TC activity remains elevated for a majority of the Pacific Island countries, and particularly in the eastern portion of the basin, including American Samoa.

Figure 10. 2015-2016 El Niño Event Infographic.

2.4.3.4 Sea Surface Temperature

Description: Monthly sea surface temperature from 2003-2015 from the Advanced Very High Resolution Radiometer (AVHRR) instrument aboard the NOAA Polar Operational Environmental Satellite (POES). These data take us back to 2003, if we were to blend this record with Pathfinder, we could reach back to 1981.

Background Below Inserted From Coastwatch West Coast Node. We would like to acknowledge the NOAA CoastWatch Program and the NOAA NWS Monterey Regional Forecast Office.

Short Description: The global area coverage (GAC) data stream from NOAA | NESDIS | OSDPD provides a high-quality sea surface temperature product with very little cloud contamination. This data is used for a variety of fisheries management projects, including the El Niño Watch Report, which stress data quality over high spatial resolution.

Technical Summary: CoastWatch offers global sea surface temperature (SST) data from the Advanced Very High Resolution Radiometer (AVHRR) instrument aboard NOAA's Polar Operational Environmental Satellites (POES). Two satellites are currently in use, NOAA-17 and NOAA-18. The AVHRR sensor is a five-channel sensor comprised of two visible radiance channels and three infrared radiance channels. During daytime satellite passes, all five radiance channels are used. During nighttime passes, only the infrared radiance channels are used.

The POES satellite stores a sub-sample of the AVHRR radiance measurements onboard, generating a global data set. The satellite downloads this dataset once it is within range of a receiving station. The sub-sampling reduces the resolution of the original data from 1.47km for the HRPT SST product to 11km for the global data product.

AVHRR radiance measurements are processed to SST by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), Office of Satellite Data Processing and Distribution (OSDPD) using the non-linear sea surface temperature (NLSST) algorithm detailed in *Walton et al., 1998*. SST values are accurate to within 0.5 degrees Celsius. Ongoing calibration and validation efforts by NOAA satellites and information provide for continuity of quality assessment and algorithm integrity (e.g., *Li et al., 2001a and Li et al., 2001b*). In addition, the CoastWatch West Coast Regional Node (WCRN) runs monthly validation tests for all SST data streams using data from the NOAA National Weather Service and National Data Buoy Center (NDBC).

The data are cloud screened using the CLAVR-x method developed and maintained by NOAA Satellites and Information (e.g., *Stowe et al., 1999*). The data are mapped to an equal angle grid (0.1 degrees latitude by 0.1 degrees longitude) using a simple arithmetic mean to produce individual and composite images of various durations (e.g., 1, 3, 8, 14-day).

Timeframe: 2003-2015, Daily data available, Monthly means shown.

Region/Location: Global.

Data Source: “SST, POES AVHRR, GAC, Global, Day and Night (Monthly Composite)” http://coastwatch.pfeg.noaa.gov/erddap/griddap/erdAGsstamday.html.

Measurement Platform: *AVHRR, POES Satellite*

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

References: Li, X., W. Pichel, E. Maturi, P. Clemente-Colón, and J. Sapper, 2001a. Deriving the operational nonlinear multi-channel sea surface temperature algorithm coefficients for NOAA-15 AVHRR/3, Int. J. Remote Sens., Volume 22, No. 4, 699 - 704.

Li, X, W. Pichel, P. Clemente-Colón, V. Krasnopolsky, and J. Sapper, 2001b. Validation of coastal sea and lake surface temperature measurements derived from NOAA/AVHRR Data, Int. J. Remote Sens., Vol. 22, No. 7, 1285-1303.

Stowe, L. L., P. A. Davis, and E. P. McClain, 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, 656-681.

Walton C. C., W. G. Pichel, J. F. Sapper, D. A. May, 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) 27999-28012.

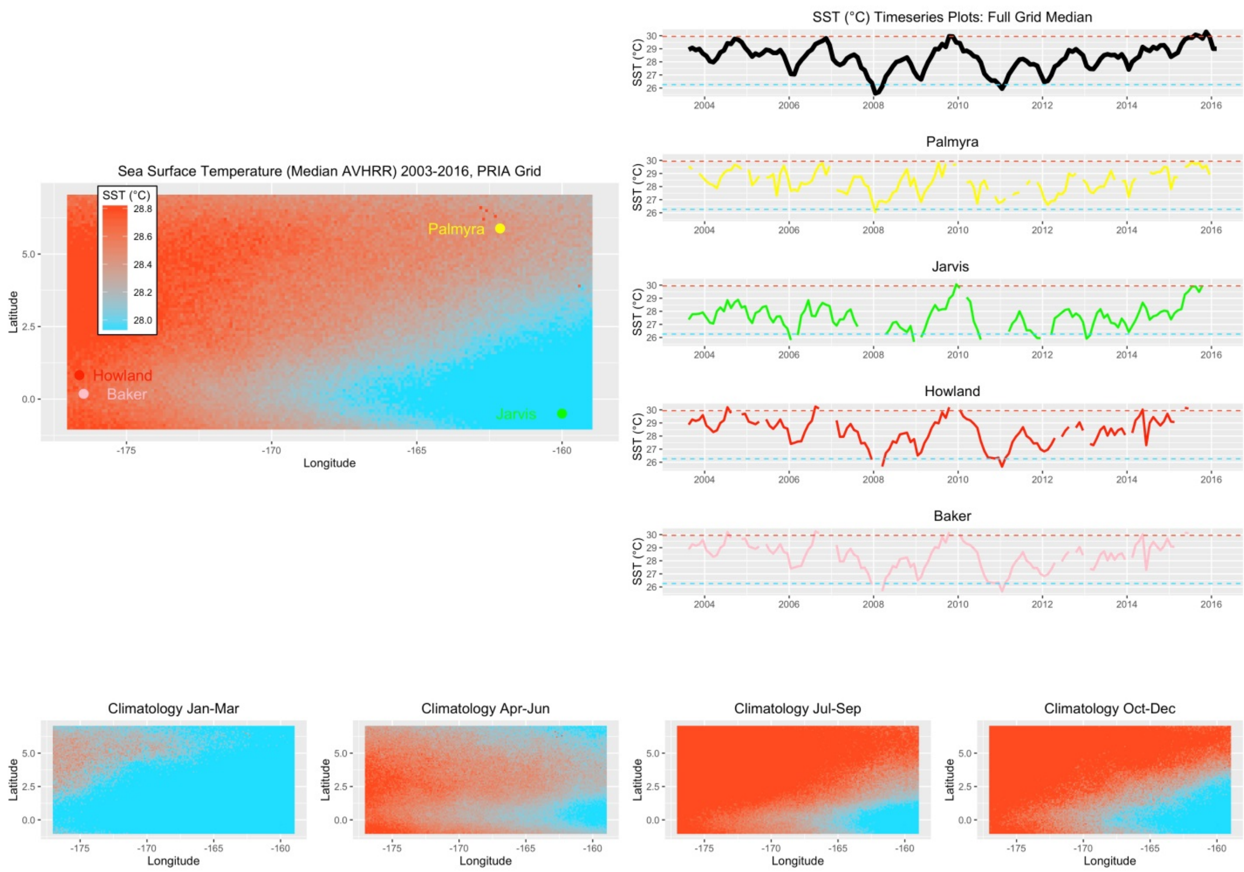


Figure 11. Sea surface temperature for Pacific Remote Island regional grid.

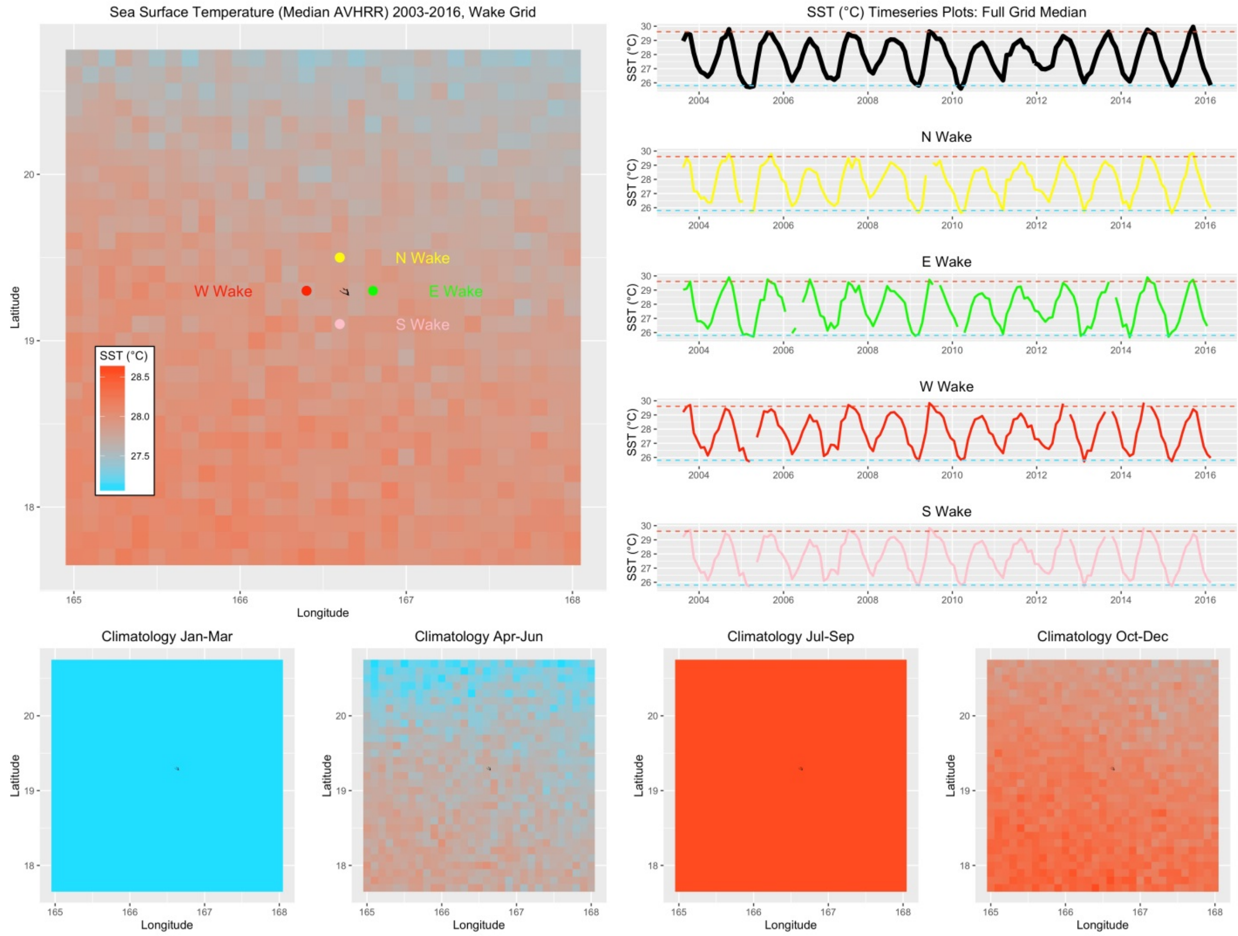


Figure 12. Sea surface temperature for Wake Island regional grid.

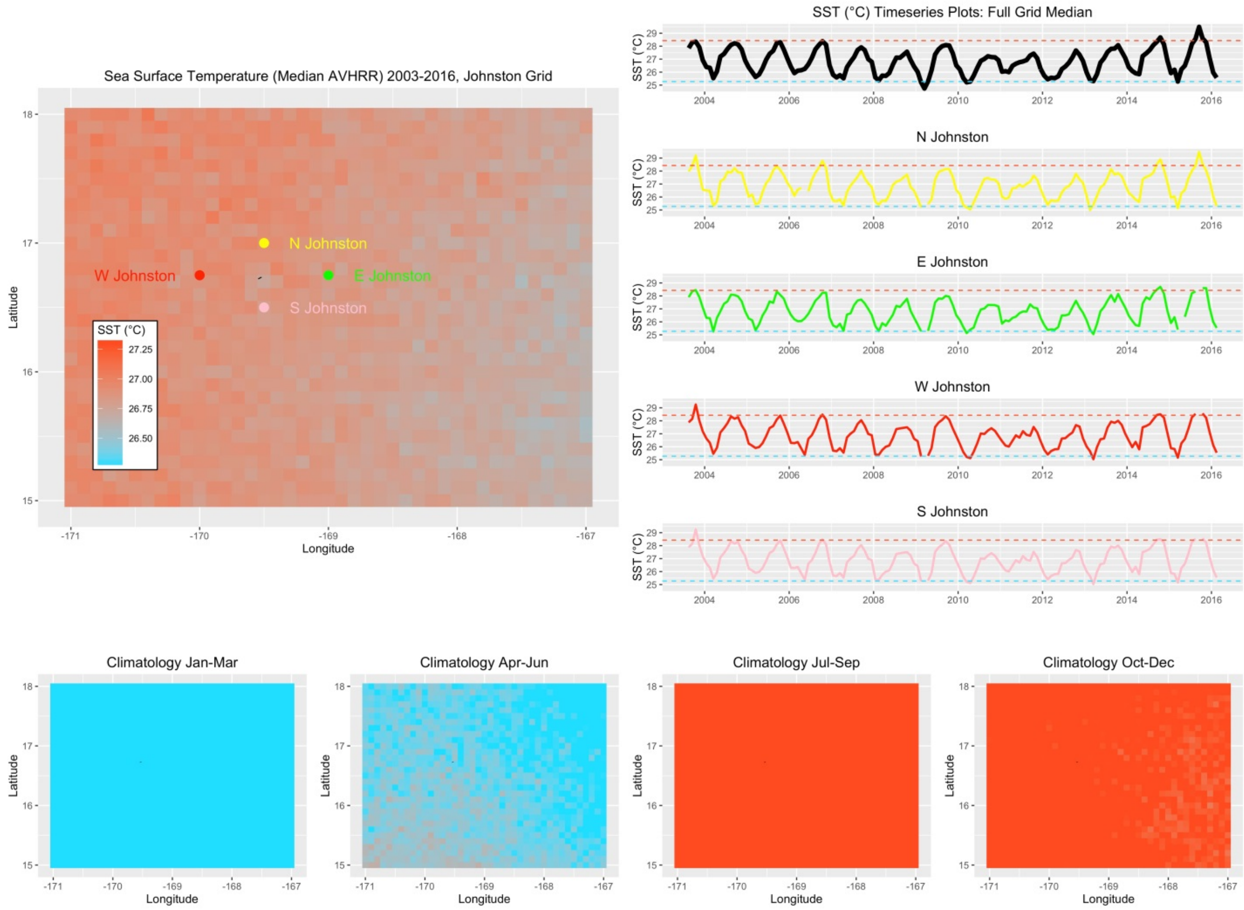


Figure 13. Sea Surface Temperature for Johnston Atoll regional grid.

2.4.3.5 Sea Surface Temperature Anomaly

Description: Monthly sea surface temperature anomaly from 2003-2015 from the AVHRR instrument aboard the NOAA Polar Operational Environmental Satellite (POES), compared against the Casey and Cornillon Climatology (Casey and Cornillion 1999). These data take us back to 2003, if we were to blend this record with Pathfinder, we could reach back to 1981.

Background below inserted from CoastWatch West Coast Node
[http://coastwatch.pfeg.noaa.gov/infog/AG_tanm_las.html]. We would like to acknowledge the NOAA CoastWatch Program and the NOAA NESDIS Office of Satellite Data Processing and Distribution.

Short Description: The SST anomaly product is used to show the difference between the surface temperature at a given time and the temperature that is normal for that time of year. This effectively filters out seasonal cycles and allows one to view intra-seasonal and inter-annual signals in the data. The global SST anomaly product is produced by comparing the AVHRR GAC SST with a climatology by *Casey and Cornillon, 1999*, for the region and time period specified. The AVHRR GAC SST is a high quality data set provided by NOAA | NESDIS | OSDPD.

Technical Summary: SST anomaly data are distributed at 11km resolution. AVHRR GAC SST values are accurate to within plus or minus 0.5 degrees Celsius. The time-averaged SST from AVHRR GAC is compared to the climatological SST from *Casey and Cornillon, 1999*, for the specific time period and region. The data are mapped to an equal angle grid of 0.1 degrees latitude by 0.1 degrees longitude using a simple arithmetic mean to produce composite images of various duration (e.g., 1, 3, 8, 14-day).

Reference: Casey, K.S. and P. Cornillon. 1999. A comparison of satellite and in situ based sea surface temperature climatologies. J. Climate. Vol. 12, no. 6, 1848-1863.

Timeframe: 2003-2015, Daily data available, Monthly means shown.

Region/Location: Global.

Data Source: "SST Anomaly, POES AVHRR, Casey and Cornillon Climatology, Global (Monthly Composite)"
http://coastwatch.pfeg.noaa.gov/erddap/griddap/erdAGtanmmday_LonPM180.html

Measurement Platform: *POES, AVHRR Satellite*

Rationale: Sea surface temperature Anomaly highlights long term trends, filtering out seasonal cycle is one of the most directly observable measures we have for tracking increasing ocean temperature.

References: Casey, K.S. and P. Cornillon. 1999. A comparison of satellite and in situ based sea surface temperature climatologies. J. Climate. Vol. 12, no. 6, 1848-1863.

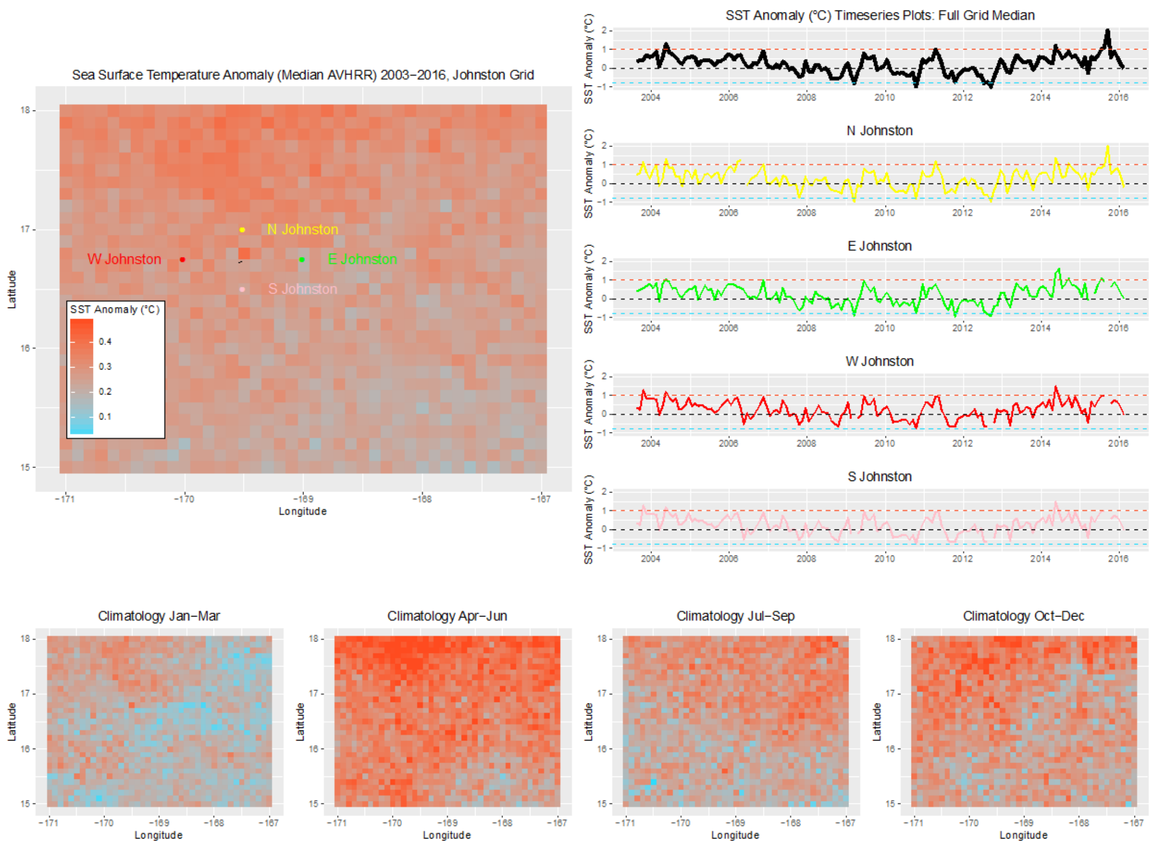


Figure 14. Sea surface temperature anomaly for Pacific remote island (Johnston Atoll) regional grid.

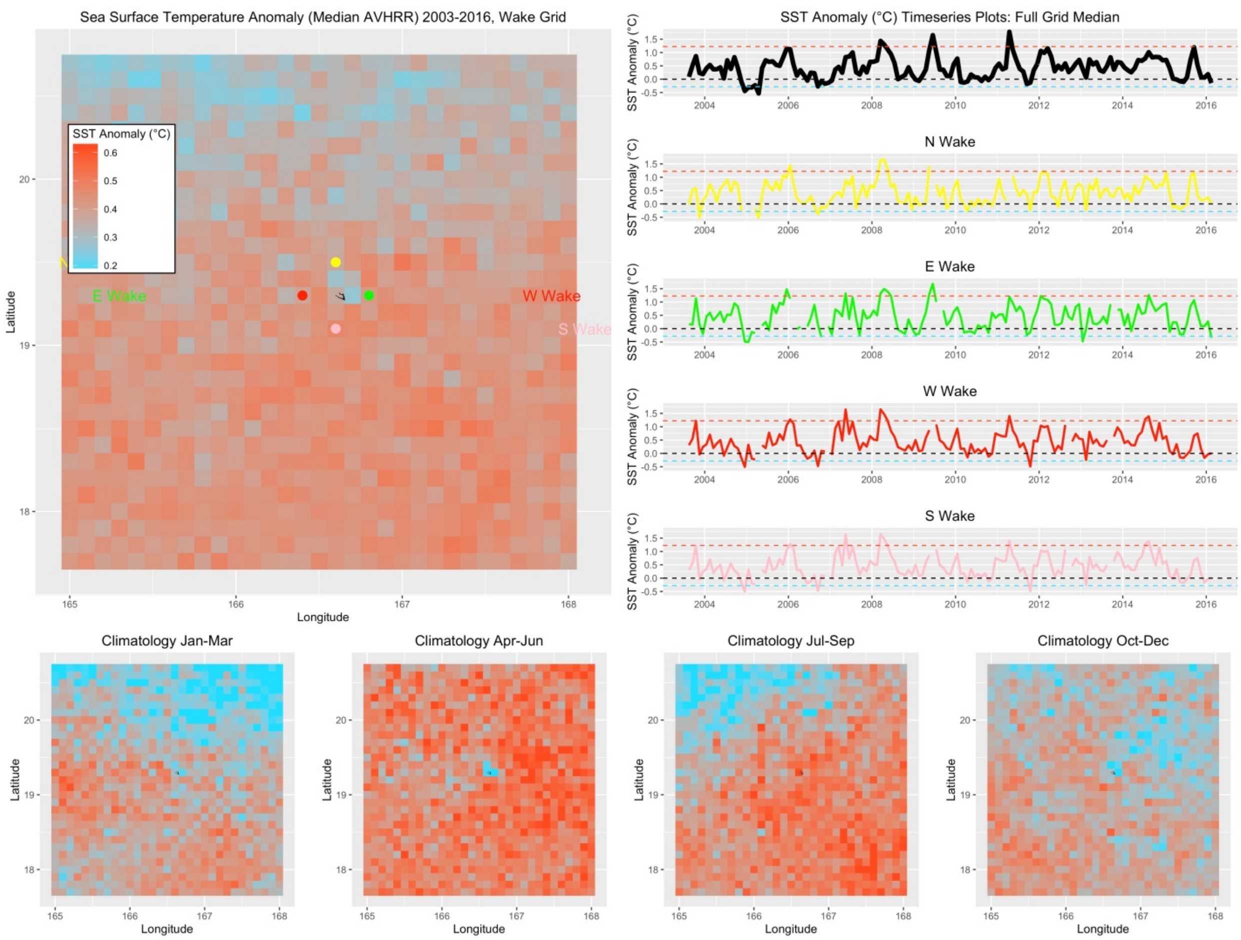


Figure 15. Sea surface temperature anomoly for Wake Island regional grid.

2.4.3.6 Heavy Weather (Tropical Cyclones)

Description: This indicator uses historical data from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) International Best Track Archive for Climate Stewardship (IBTrACS) 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 and the Power Dissipation Index (PDI) which are two ways of monitoring the frequency, strength, and duration of tropical cyclones based on wind speed measurements.

The annual frequency of storms passing through the western North Pacific basin is tracked and a stacked time series plot will show the representative breakdown of the Saffir-Simpson hurricane categories. Three solid lines across the graph will also be plotted representing a) the annual long-term average number of named storms, b) the annual average number of typhoons, and c) the annual average number of major typhoons (Cat 3 and above). Three more lines will also be shown (in light gray) representing the annual average number of named-storms for ENSO a) neutral, b) warm, and c) cool.

Every cyclone has an ACE Index value, which is a number based on the maximum wind speed measured at six-hourly intervals over the entire time that the cyclone is classified as at least a tropical storm (wind speed of at least 34 knots; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. This plot will show the historical ACE values for each typhoon season and will have a solid line representing the annual average ACE value. Three more lines will also be shown (in light gray) representing the annual average ACE values for ENSO a) neutral, b) warm, and c) cool.

Timeframe: Yearly

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

Data Source/Responsible Party: NCDC'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.

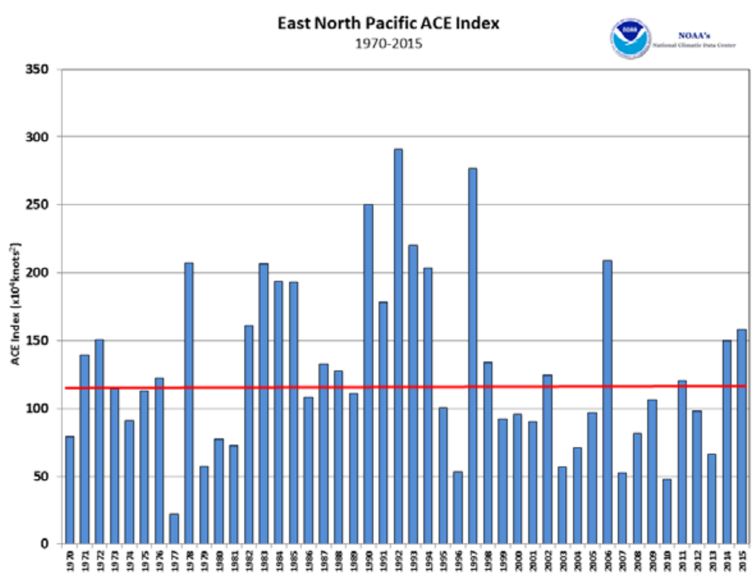


Figure 16. 2015 East Pacific Tropical Cyclone ACE 1970-2015. Source: NOAA's National Hurricane Center.

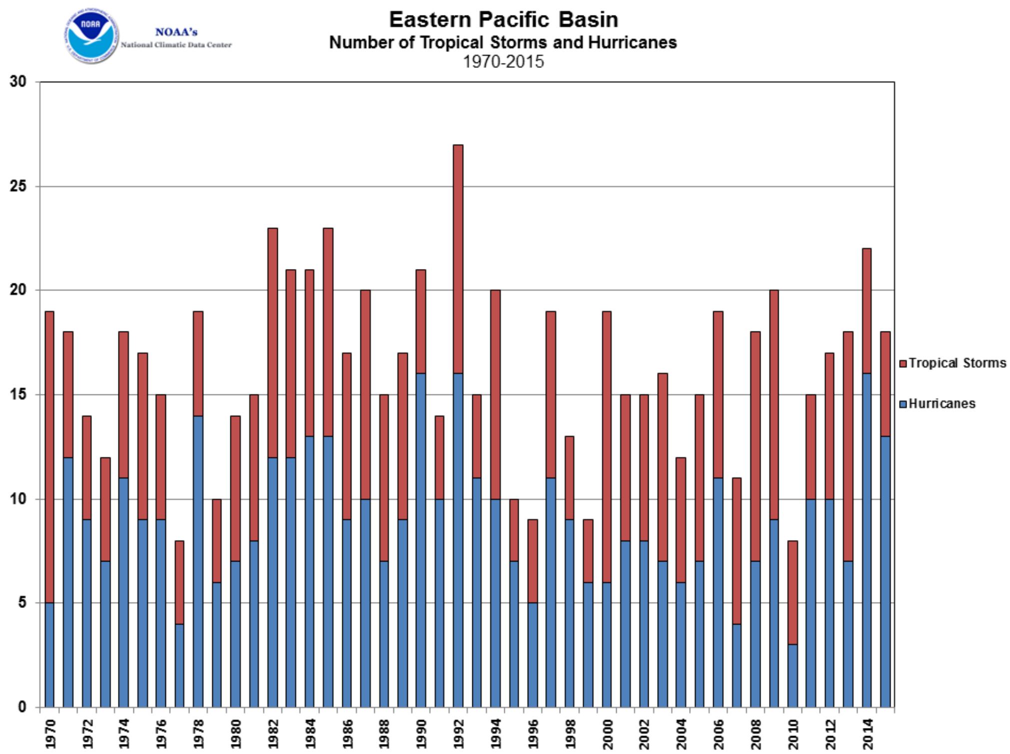


Figure 17. East Pacific Tropical Cyclone Count 1970-2015. Source: NOAA's National Hurricane Center.

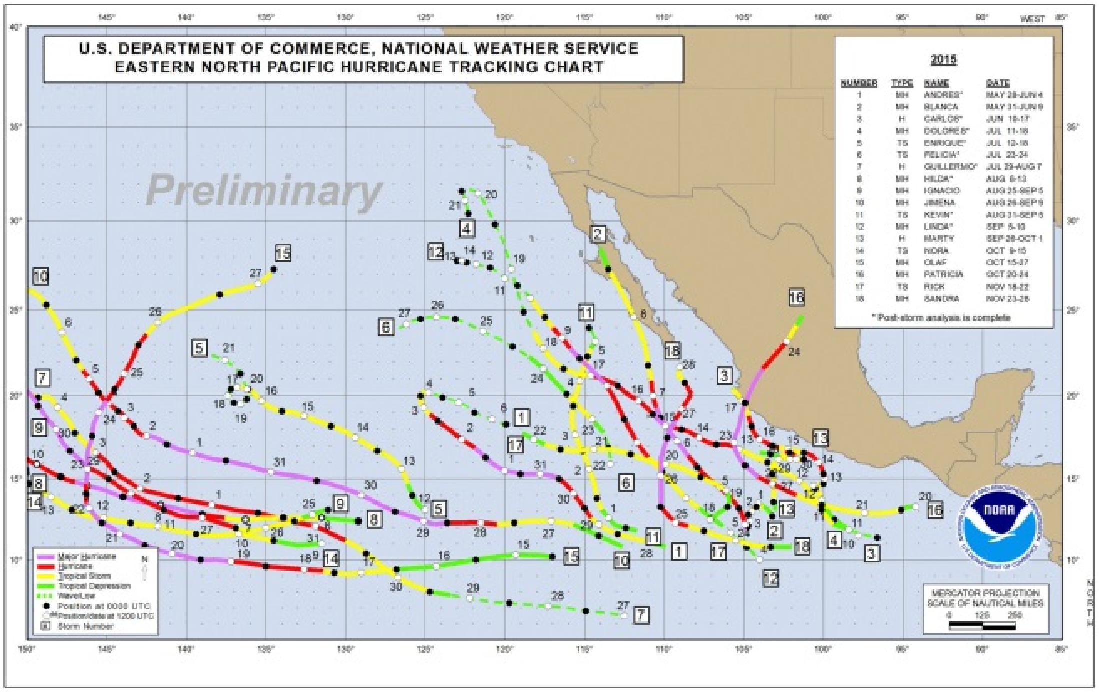


Figure 18. eastern Pacific Cyclone Tracks. Source: NOAA's National Hurricane Center.

The NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2015, published online January 2016, notes that "the 2015 East Pacific hurricane season had 18 named storms, including 13 hurricanes, nine of which became major. The 1981-2010 average number of named storms in the East Pacific is 16.5, with 8.9 hurricanes, and 4.3 major hurricanes. This is the first year since reliable record keeping began in 1971 that the eastern Pacific saw nine major hurricanes. The Central Pacific also saw an above-average tropical cyclone season, with 14 named storms, eight hurricanes, and five major hurricanes, the most active season since reliable record-keeping began in 1971. Three major hurricanes (Ignacio, Kilo and Jimena) were active across the two adjacent basins at the same time, the first time this occurrence has been observed. The ACE index for the East Pacific basin during 2015 was 158 ($x10^4$ knots^2), which is above the 1981-2010 average of 132 ($x10^4$ knots^2) and the highest since 2006. The Central Pacific basin ACE during 2015 was 124 ($x10^4$ knots^2)." Inserted from **http://www.ncdc.noaa.gov/sotc/tropical-cyclones/201513**

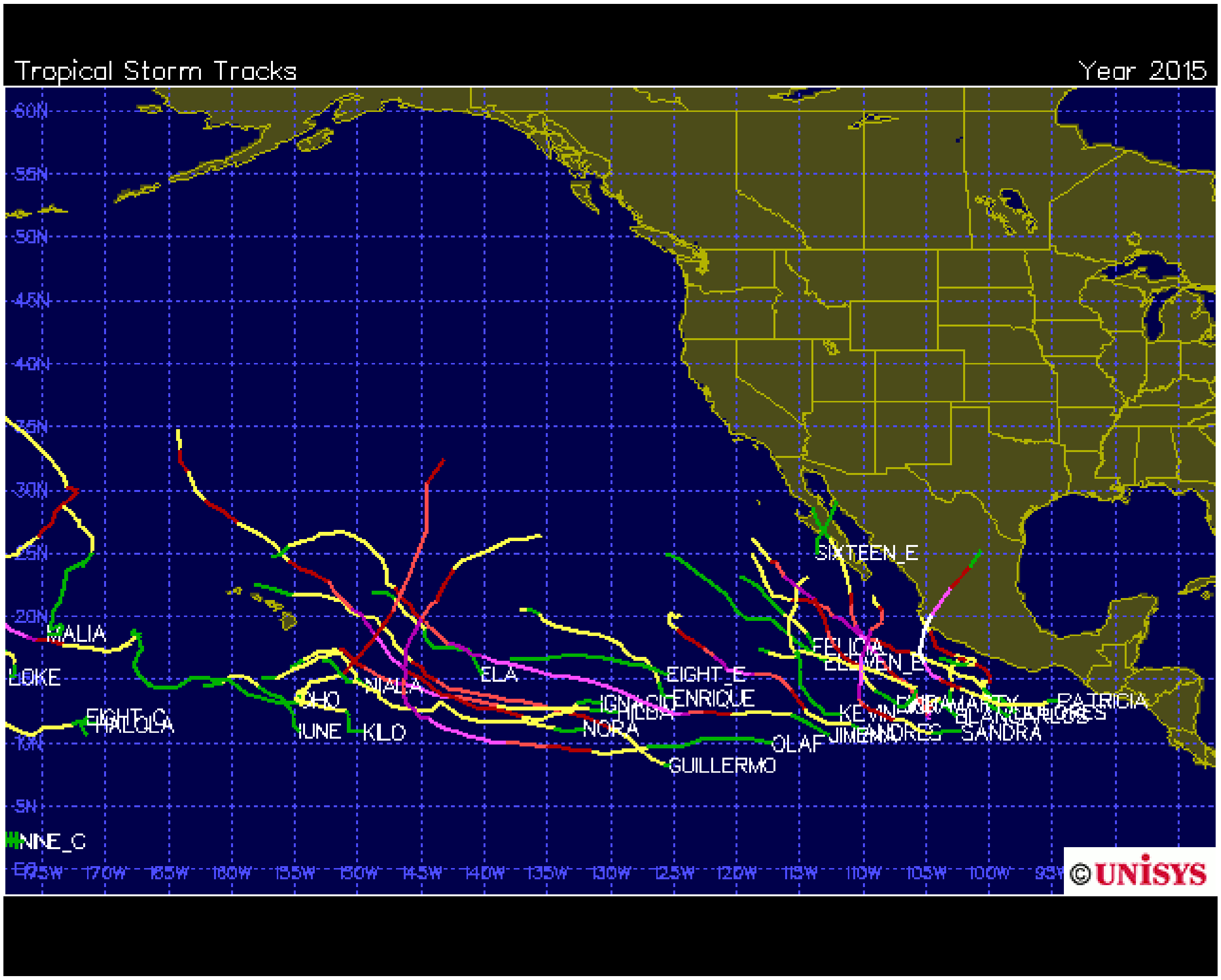


Figure 19. Eastern Pacific Cyclone Tracks in 2015. Source: (http://weather.unisys.com/hurricane/e_pacific/2015).

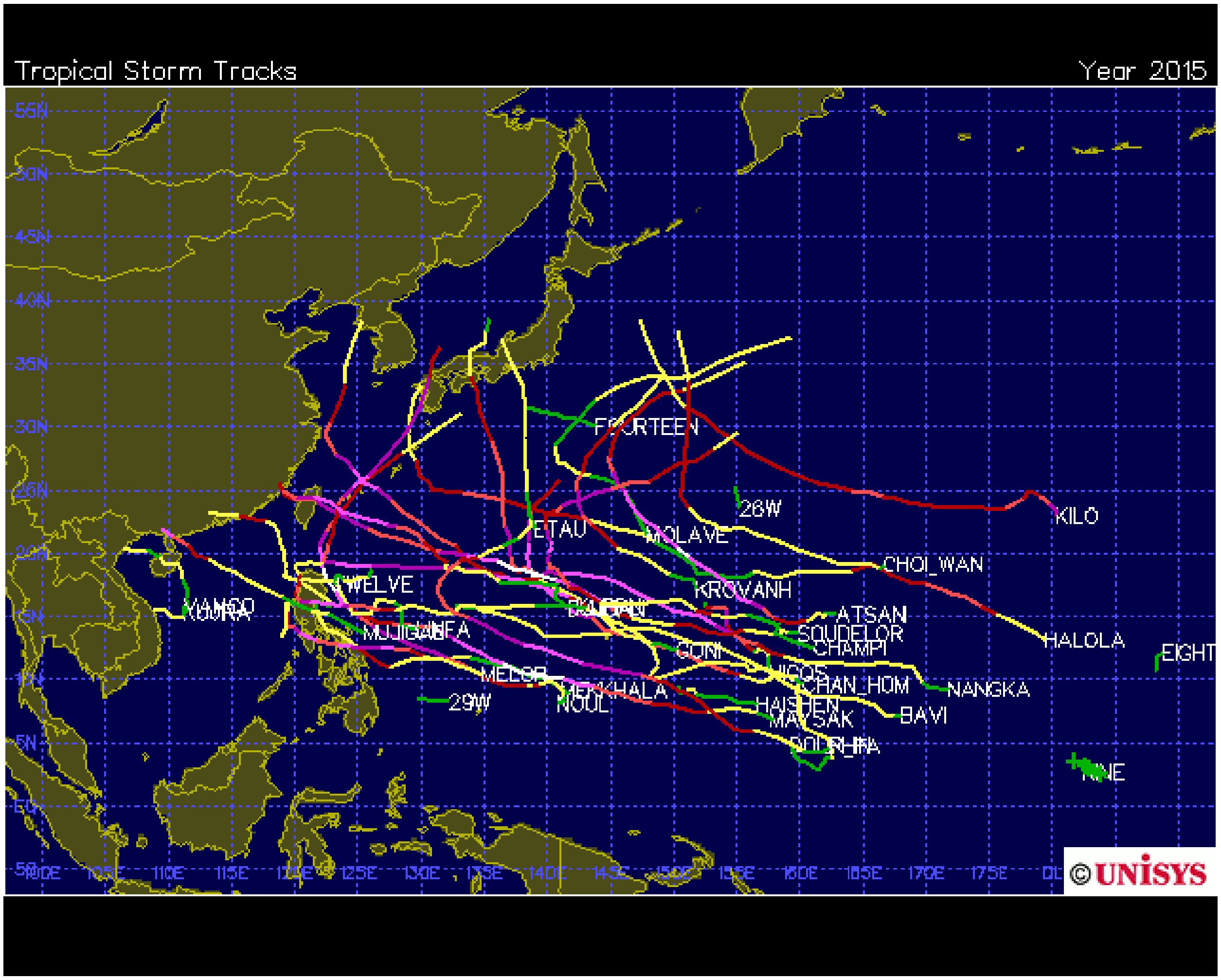


Figure 20. Western Pacific Cyclone Tracks in 2015. Source: http://weather.unisys.com/hurricane/w_pacific/2015.

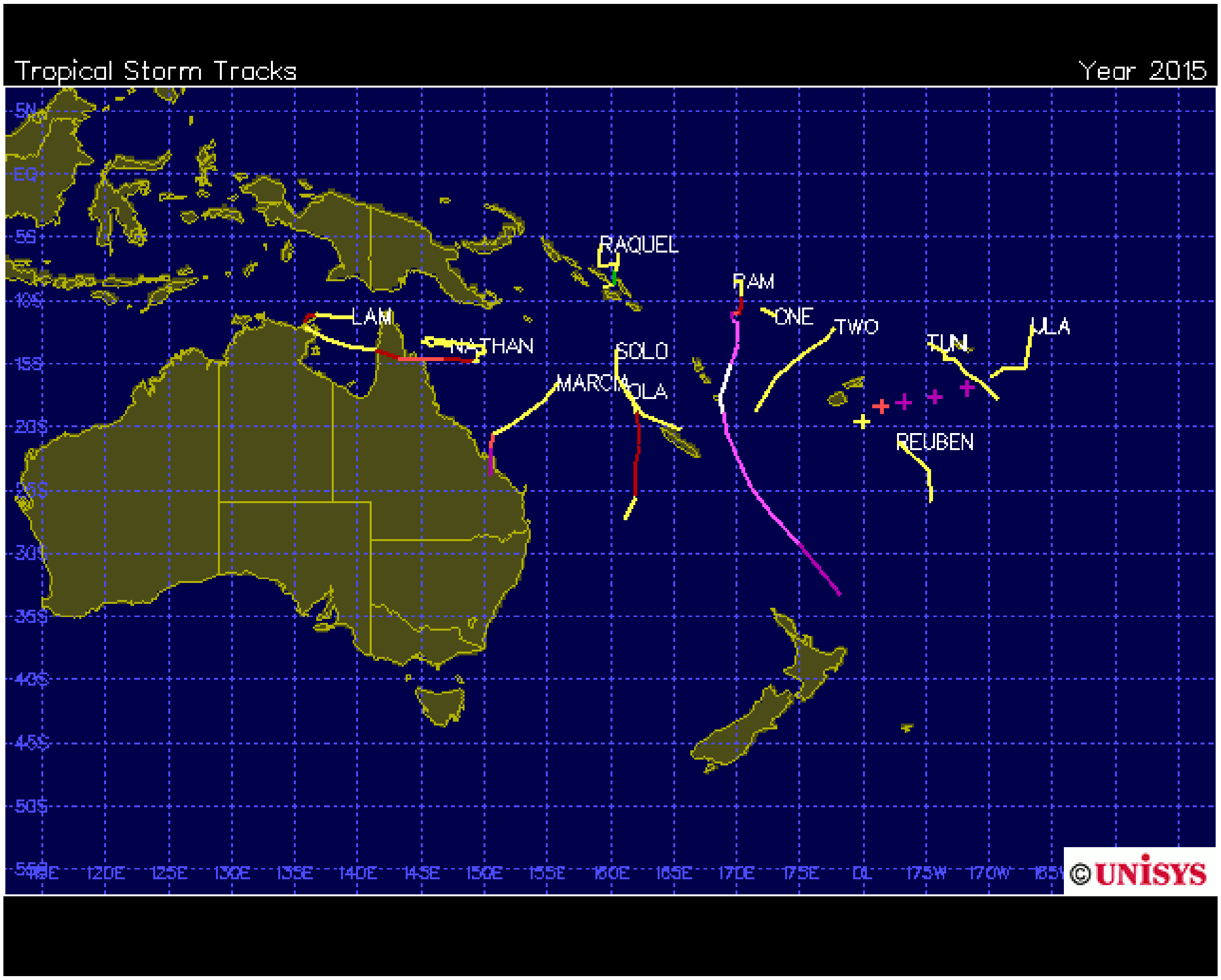


Figure 21. Southern Pacific Cyclones in 2015. Source: http://weather.unisys.com/hurricane/w_pacific.

References: NOAA National Centers for Environmental Information, State of the Climate: Hurricanes and Tropical Storms for Annual 2015, published online January 2016, retrieved on August 5, 2016 from http://www.ncdc.noaa.gov/sotc/tropical-cyclones/201513.

2.4.3.7 Sea Level (Sea Surface Height and Anomaly)

Description: Monthly mean sea level time series, including extremes

Timeframe: Monthly

Region/Location: Basinwide

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

Measurement Platform: Satellite

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.

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.

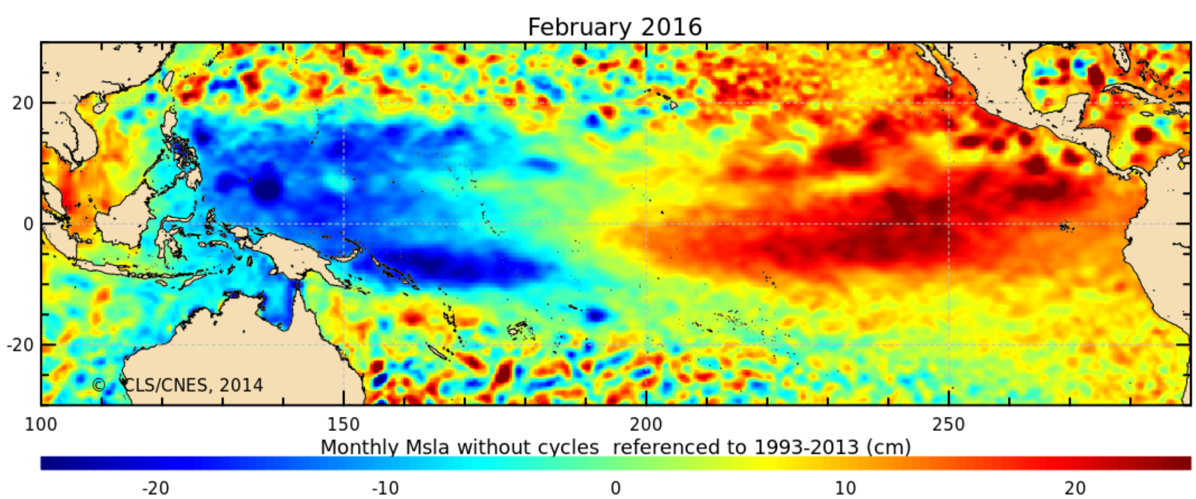
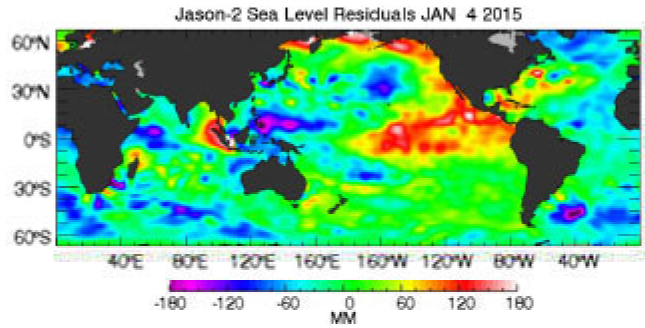
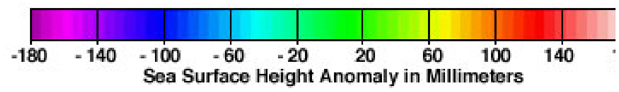
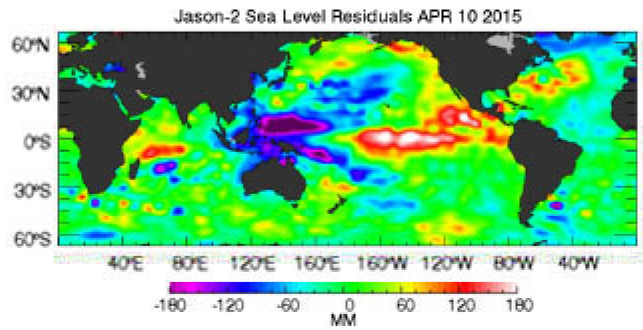


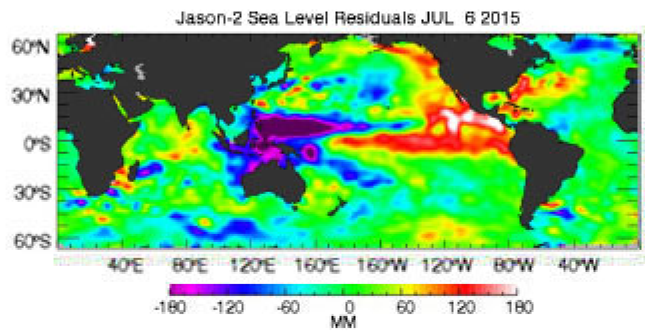
Figure 22. Basin wide mean sea level anomaly for February 2016 compared to 1993-2013 climatology from satellite altimetry.

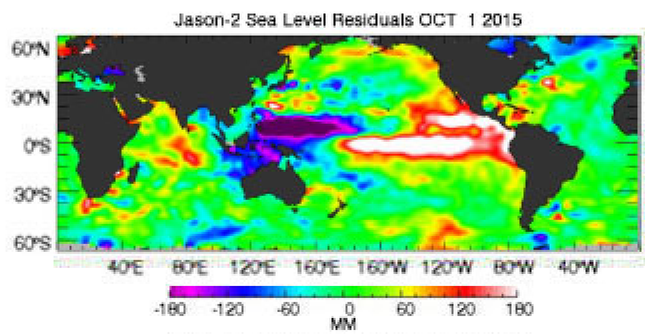


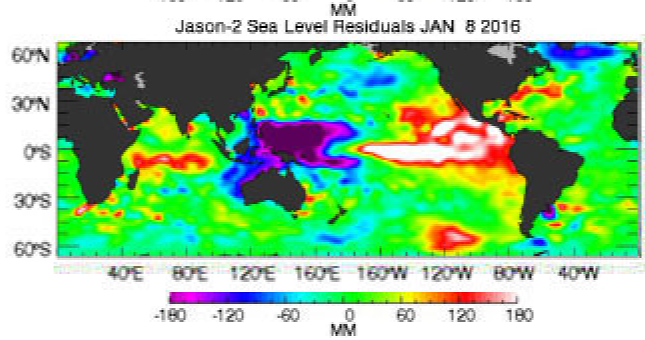
Quarterly time series of mean sea level anomalies during 2015 provide a glimpse into the evolution of the 2015-2016 El Niño throughout the year using satellite altimetry measurements of sea level height (http://sealevel.jpl.nasa.gov/science/elninopdo/latestdata/archive/index.cfm?y=2015)











2.4.3.8 Wave Watch 3 Global Wave Model

Description: To describe patterns in wave forcing, we present data from the Wave Watch 3 global wave model run by the Department of Ocean and Resources Engineering at the University of Hawaiʻi in collaboration with NOAA/NCEP and NWS Honolulu. PacIOOS describes the model at http://oos.soest.hawaii.edu/pacioos/focus/modeling/wave_models.php: "The global model is initialized daily and is forced with NOAA/NCEP's global forecast system (GFS) winds. This model is designed to capture the large-scale ocean waves, provide spectral boundary conditions for the Hawaiʻi and Mariana Islands regional WW3 model, and most importantly, the 7 day model outputs a 5 day forecast."

Data presented here come from the global model, but regional WW3 models with higher resolution exist for Hawaii, Marianas and Samoa, and in some cases, very high resolution SWAN models exist for islands within those groups.

Timeframe: 2010-2016, Daily data.

Region/Location: Global.

Data Source: "WaveWatch III (WW3) Global Wave Model": http://oos.soest.hawaii.edu/erddap/griddap/NWW3_Global_Best.html

Measurement Platform: *Global Forecast System Winds, WW3 model*

Rationale: Wave forcing can have major implications for both coastal ecosystems and pelagic fishing operations.

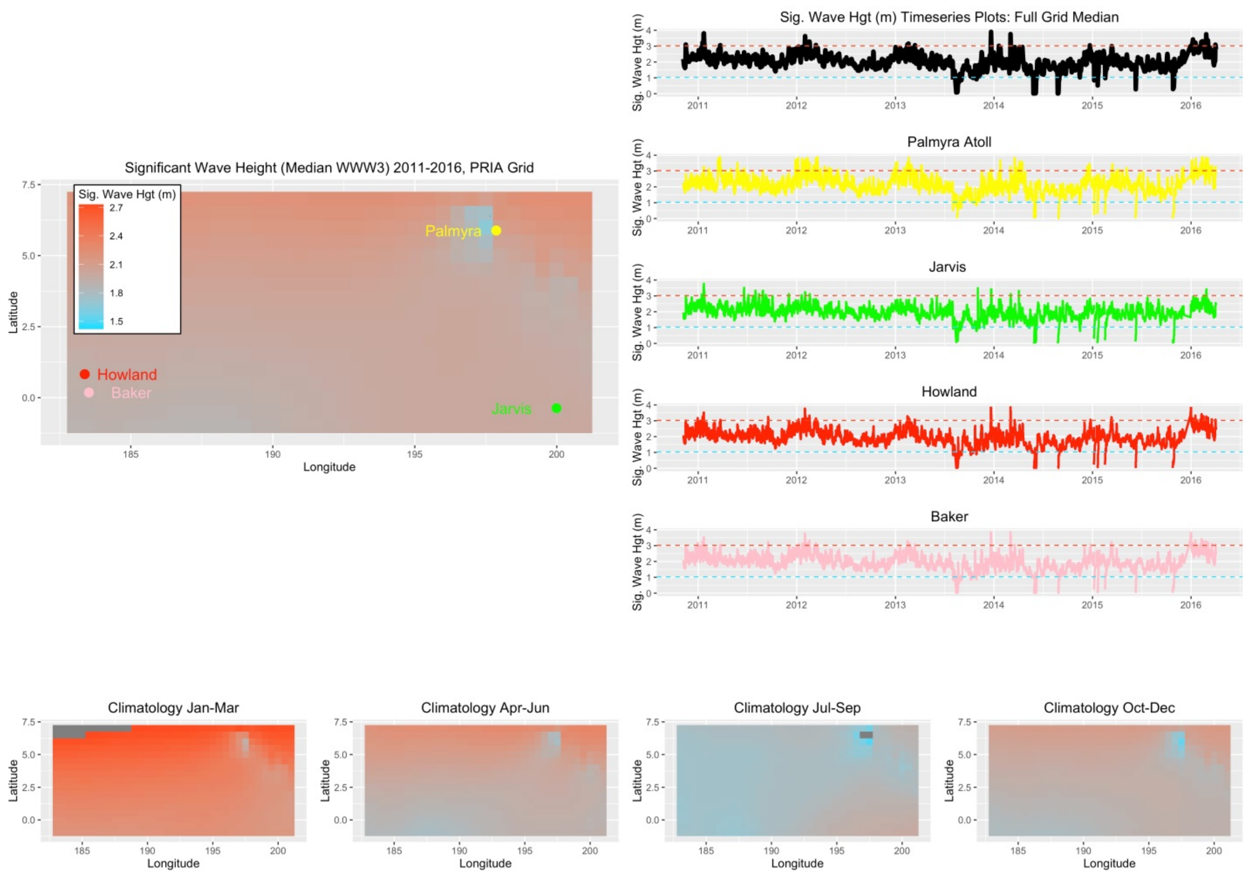


Figure 23. Wave watch summary for Pacific remote island grid.

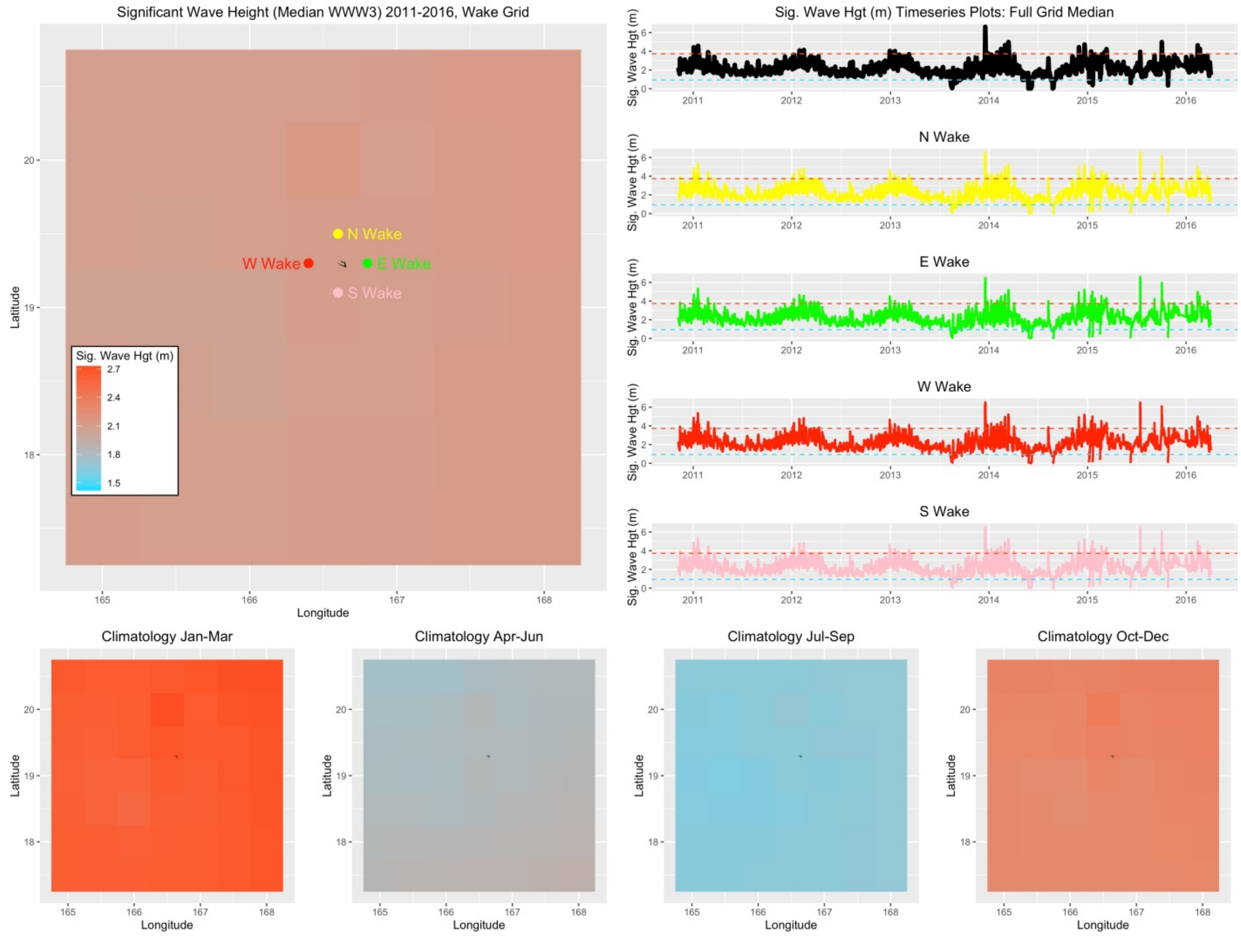


Figure 24. wave watch summary for Wake Island grid.

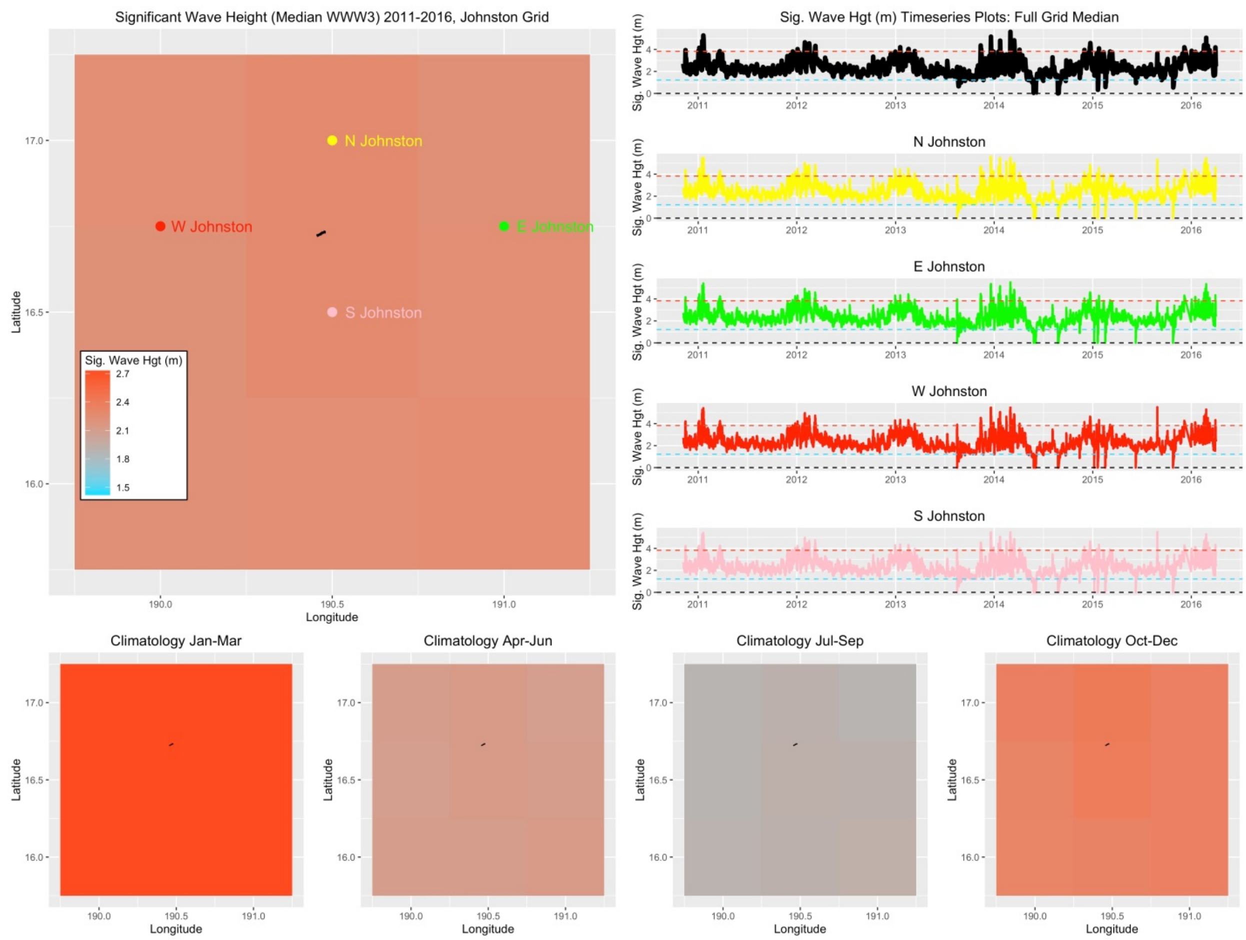


Figure 25. Wave watch summary for Johnston Atoll grid.

2.4.4 Observational and Research Needs

Through preparation of the 2015 Archipelagic Annual Reports, the Council has identified a number of observational and research needs that, if addressed, would improve the information content of future Climate and Ocean Indicators chapters. This information would provide fishery managers, fishing industry and community stakeholders with better understanding and predictive capacity vital to sustaining resilient and vibrant fishery systems in the Western Pacific.

- Emphasize the importance of continuing the climate and ocean indicators used in this report so that a consistent, long-term record can be maintained;
- Develop agreements among stakeholders and research partners to ensure the sustainability, availability and accessibility of climate and ocean indicators, their associated datasets and analytical methods used in this and future reports;
- Improve monitoring and understanding of the impacts of changes in ocean temperature, pH and ocean acidity, ocean oxygen content and hypoxia, and sea level rise through active collaboration by all fishery stakeholders and research partners;
- Develop, test and provide access to additional climate and ocean indicators that can improve the Archipelagic Conceptual Model;

- Investigate the connections between climate variables and other indicators in the Archipelagic Conceptual Model to improve understand of changes in physical, biochemical, biologic and socio-economic processes and their interactions in the regional ecosystem;
- Explore connections among sea surface conditions, stratification and mixing;
- Improve understanding of mahi and swordfish size in relation to the orientation of the TZCF;
- Explore the biological implications of tropical cyclones;
- Standardize fish community size structure data for gear type;
- Develop predictive models that can be used for scenario planning to account for unexpected changes and uncertainties in the regional ecosystem and fisheries;
- Foster applied research in ecosystem modeling to better describe current conditions and to better anticipate the future under alternative models of climate and ocean change including changes in expected human benefits and their variability;
- Clarify and elucidate the interactions among (1) changes in climate, (2) ecosystems and (3) social, economic and cultural impacts on fishing communities;
- Explore the implications and effectiveness of large marine protected areas including intergenerational losses of knowledge due to lack of access to traditional fishing areas.
- Cultural knowledge and practices for adapting to changing climate in the past and how they might contribute to future climate adaptation.
- Enhanced information on social, economic and cultural impacts of a changing climate and increased pressure on the ocean and its resources.
- Analysis of potential relationship(s) between traditional runs of fish and climate change indicators.
- Explore the use of electronic monitoring and autonomous vehicles including small vessel prototypes.
- Cultural knowledge and practices for adapting to changing climate in the past and how they might contribute to future climate adaptation.
- Explore additional and/or alternative climate and ocean indicators that may have important effects on archipelagic fisheries systems including:
    - Ocean currents and anomalies;
    - Near-surface wind velocities and anomalies;
    - Wave forcing anomalies and wave power;
    - Sea level and extremes data in the absence of tide gauges;
    - Estimates of phytoplankton abundance and size from satellite remotely-sensed SST and chlorophyll measurements;
    - Nutrients;
    - Eddy kinetic energy (EKE) which can be derived from satellite and remotely-sensed sea surface height data and can be indicative of productivity-enhancing eddies;
    - Degree Heating Weeks for coral reef ecosystems;
    - Time series of species richness and diversity from catch data which could potentially provide insight into how the ecosystem is responding to physical climate influences; and

- Identifying and monitoring key socio-economic and cultural indicators of the impacts of changing climate on resources, fishing communities, operations and resilience.

2.4.5 A Look to the Future

Future Annual Reports will include additional indicators as they become available and their relevance to the development, evaluation and revision of ecosystem-fishery plans becomes clear. Working with national and jurisdictional partners, the Council will make all datasets used in the preparation of this and future reports available and easily accessible.

2.5 Essential Fish Habitat

2.5.1 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.” 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 five years (600.815(a)(10)). The council’s FEPs state that new EFH information should be reviewed, as necessary, during preparation of the annual reports by the Plan Teams. Additionally, the EFH Final Rule states “Councils should report on their review of EFH information as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to §600.315(e).” The habitat portion of the annual 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. To this point, the annual report summarizes the available information on habitat condition for all fisheries.

2.5.2 EFH Information

The EFH components of fisheries management plans include the description and identification of EFH, lists of prey species and locations for each managed species, and optionally, habitat areas of particular concern. Impact-oriented components of FMPs include federal fishing activities that may adversely affect EFH; non-federal fishing activities that may adversely affect EFH; non-fishing activities that may adversely affect EFH; conservation and enhancement recommendations; and a cumulative impacts analysis on EFH. The last two components include the research and information needs section, which feeds into the Council's Five Year Research Priorities, and the EFH update procedure, which is described in the FEP but implemented in the annual 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 Pacific Remote Island Area (PRIA) FEP describes EFH for the BMUS, CMUS, CREMUS, and PCMUS. The 2015 SAFE report summarizes the precious corals EFH information, which was prioritized for review in 2015 by Council, PIRO, and PIFSC habitat staff because the Council's consideration of EFH was most out of date with respect to available abundance information.

2.5.2.1 Habitat Objectives of FEP

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

a. 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

b. 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, resetting the five-year timeline for review of the precious corals fishery. The Council's support of non-fishing activities research is monitored through the program plan and five year research priorities, not the annual report.

2.5.2.2 Response to Previous Council Recommendations

At its 163rd meeting in Honolulu, HI, the Council endorsed a plan team working group on the HAPC process: "The working group will produce a report exploring HAPC designation options for the Western Pacific region within a year." The working group report is included as Appendix 1 to the habitat section of this report.

At its 165th meeting in Honolulu, HI, the Council recommended the revised Regional Operating Agreement be adopted as presented including the ESA-MSA Integration Agreement, Action Plan Template and Council diagram as appendixes and directs staff to finalize the EFH Policy to include the five-year EFH review and the EFH consultation coordination processes. The Council endorsed the inclusion of major federal actions with more than minimal adverse effect on EFH and those identified by the Council or its advisory bodies in the scope of the EFH consultation agreement.

In developing the EFH policy, staff will consider the HAPC Process working group report findings.

There are no additional outstanding PRIA habitat recommendations for the plan team.

2.5.3 Habitat Use by MUS and Trends in Habitat Condition

The Pacific Remote Island Areas comprise the U.S. possessions of Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Kingman Reef, Wake Island, Palmyra Atoll, and Midway Atoll (Figure 26). However, because Midway is located in the Hawaiian archipelago, it is included in the Hawaii Archipelago FEP[2]. Therefore, neither the "Pacific Remote Island Areas" nor "PRIA" include Midway Atoll, for the purpose of federal fisheries management.

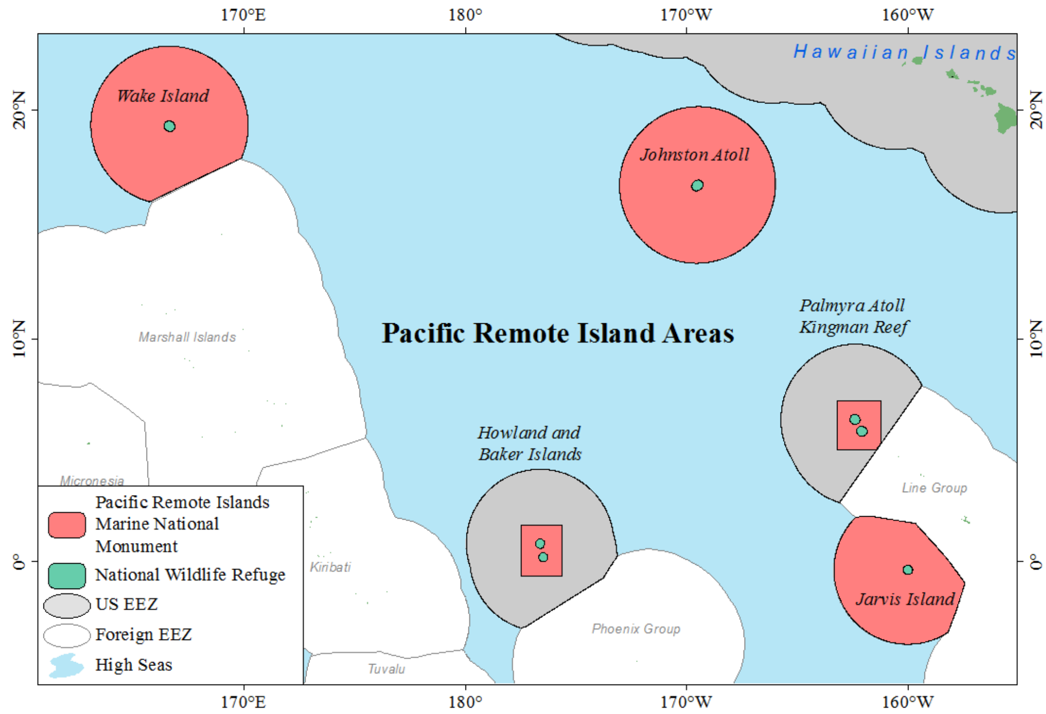


Figure 26. Pacific Remote Island Areas.

Baker Island is part of the Phoenix Islands archipelago. It is located approximately 1,600 nautical miles to the southwest of Honolulu at 0° 13' N and 176° 38' W. Baker is a coral-topped seamount surrounded by a narrow-fringing reef that drops steeply very close to the shore. The total amount of emergent land area of Baker Island is 1.4 square kilometers.

Howland Island lies approximately 35 miles due north of Baker Island and is also part of the Phoenix Islands archipelago. The island, which is the emergent top of a seamount, is fringed by a

[2] Midway is not administered civilly by the State of Hawaii.

relatively flat coral reef that drops off sharply. Howland Island is approximately 1.5 miles long and 0.5 miles wide. The island is flat and supports some grasses and small shrubs. The total land area is 1.6 square kilometers.

Jarvis Island, which is part of the Line Island archipelago, is located approximately 1,300 miles south of Honolulu and 1,000 miles east of Baker Island. It sits 23 miles south of the Equator at 160° 01' W. Jarvis Island is a relatively flat, sandy coral island with a 15–20-ft beach rise. Its total land area is 4.5 square kilometers. It experiences a very dry climate.

Palmyra Atoll is a low-lying coral atoll system comprised of approximately 52 islets surrounding three central lagoons. It is approximately 1,050 nautical miles south of Honolulu and is located at 5° 53' N and 162° 05' W. It is situated about halfway between Hawaii and American Samoa. Palmyra Atoll is located in the intertropical convergence zone, an area of high rainfall.

Kingman Reef is located 33 nautical miles northwest of Palmyra Atoll at 6° 23' N and 162° 24' W. Along with Palmyra, it is at the northern end of the Line Island archipelago. Kingman is actually a series of fringing reefs around a central lagoon with no emergent islets that support vegetation.

Wake Island is located at 19° 18' N and 166° 35' E, and is the northernmost atoll of the Marshall Islands group, located approximately 2,100 miles west of Hawaii. Wake Island has a total land area of 6.5 square kilometers and comprises three islets: Wake, Peale, and Wilkes.

Johnston Atoll is located at 16° 44' N and 169° 31' W and is approximately 720 nautical miles southwest of Honolulu. French Frigate Shoals in the NWHI, about 450 nautical miles to the northwest, is the nearest land mass. Johnston Atoll is an egg-shaped coral reef and lagoon complex comprised of four small islands totaling 2.8 square kilometers. The complex resides on a relatively flat, shallow platform approximately 34 kilometers in circumference. Johnston Island, the largest and main island, is natural, but has been enlarged by dredge and fill operations. Sand Island is composed of a naturally-formed island on its eastern portion and is connected by a narrow, man-made causeway to a dredged coral island at its western portion. The remaining two islands, North Island and East Island, are completely man-made from dredged coral.

All commercial activity is prohibited within the Pacific Remote Island Area Marine National Monument, which is 50 nautical miles surrounding Palmyra Atoll and Kingman Reef and Howland and Baker Islands, and the entire US EEZ surrounding Johnston Atoll, Wake, and Jarvis Island.

Essential fish habitat in the PRIA for the four MUS comprises all substrate from the shoreline to the 700 m isobath (Figure 27). 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 PRIA have been the subject of a comprehensive monitoring program through the PIFSC Coral Reef Ecosystem Division (CRED) biennially since 2002, surveys are focused on the nearshore environments surrounding the islands, atolls and reefs (PIBHMC).

The mission of the PIFSC Coral Reef Ecosystem Division (CRED) 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). CRED'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). CRED 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.

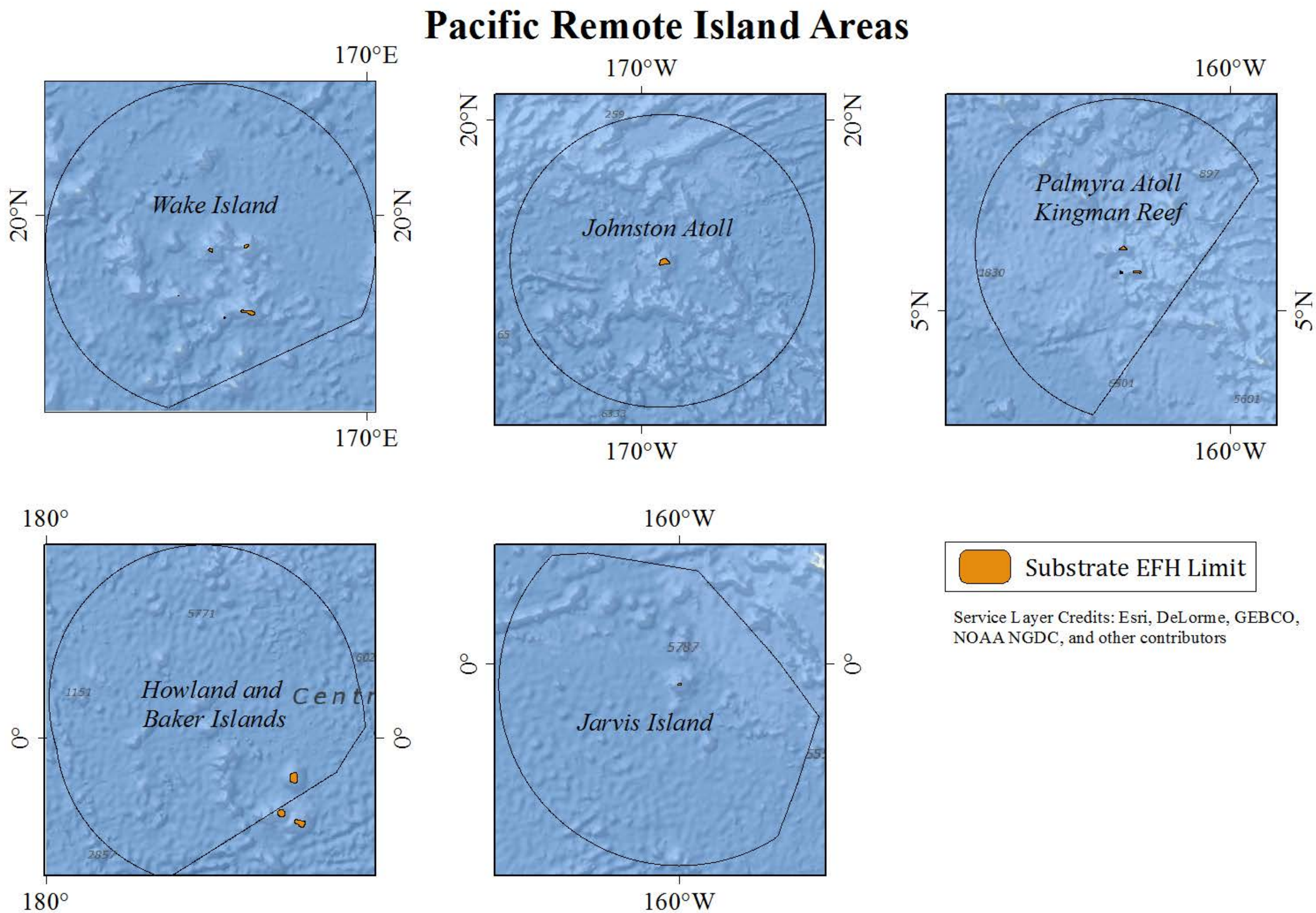


Figure 27. Substrate EFH Limit of 700 m isobath around the PRIA. Data Source: GMRT.

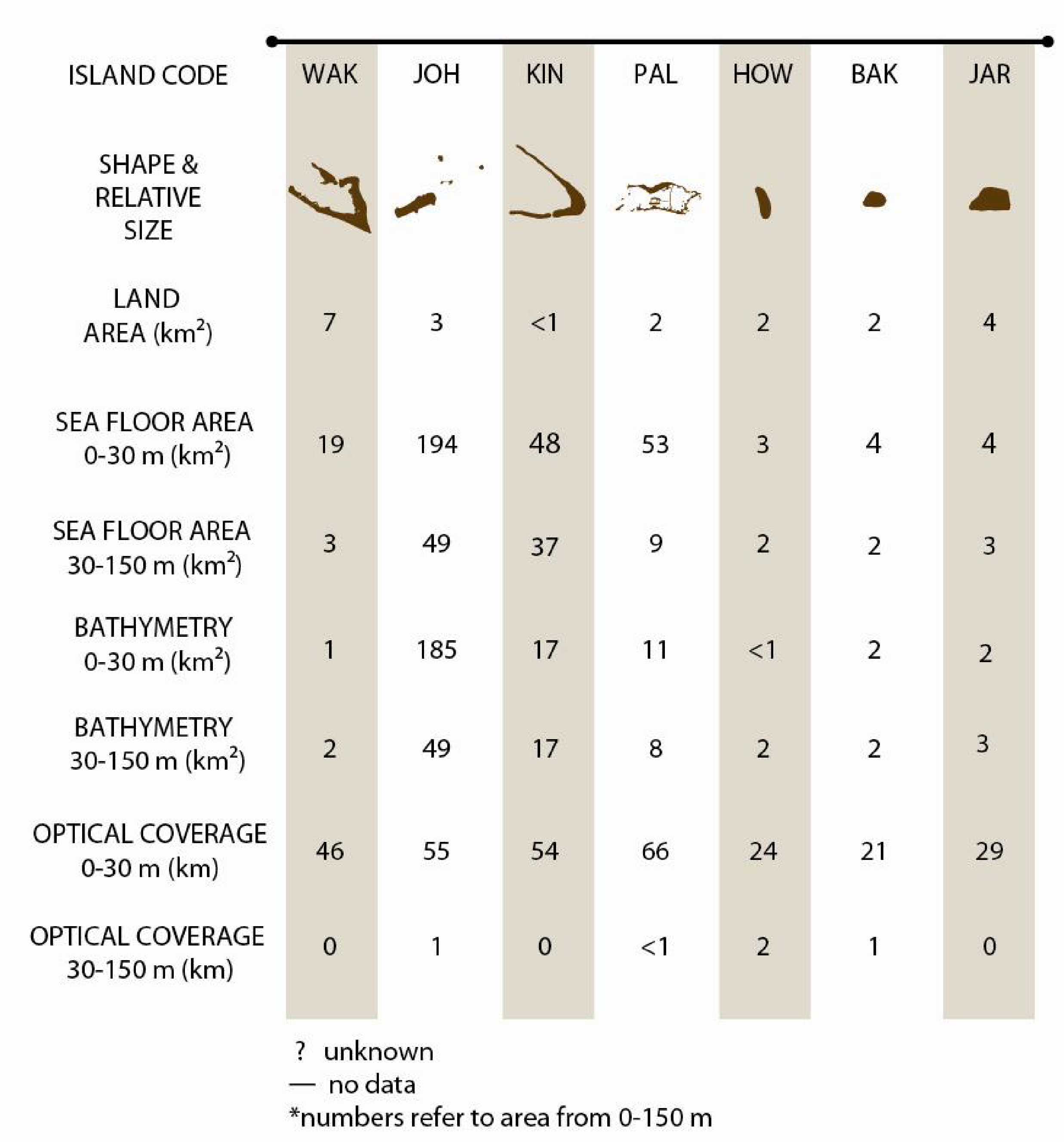
2.5.1.1 Habitat Mapping

Mapping products for the PRIA are available from the Pacific Islands Benthic Habitat Mapping Center.

Table 3. Summary of habitat mapping in the PRIA.

Depth Range	**Timeline/Mapping Product**	**Progress**	**Source**
0-30 m	IKONOS Benthic Habitat Maps	Palmyra only	CRCP 2011
	2000-2010 Bathymetry	67%	DesRochers 2016
	2011-2015 Multibeam Bathymetry		DesRochers 2016
	2011-2015 Satellite Worldview 2 Bathymetry	1%	DesRochers 2016
30-150 m	2000-2010 Bathymetry	79%	DesRochers 2016
	2011-2015 Multibeam Bathymetry	-	DesRochers 2016
15 to 2500 m	Multibeam bathymetry	Complete at Jarvis, Howland, and Baker Islands	Pacific Islands Benthic Habitat Mapping Center
	Derived Products	Backscatter available for all Geomorphology products for Johnston, Howland, Baker, Wake	Pacific Islands Benthic Habitat Mapping Center

The land and seafloor area surrounding the islands and atolls of the PRIA as well as primary data coverage are reproduced from CRCP 2011 in Figure 28.



ISLAND CODE	WAK	JOH	KIN	PAL	HOW	BAK	JAR
SHAPE & RELATIVE SIZE							
LAND AREA (km²)	7	3	<1	2	2	2	4
SEA FLOOR AREA 0-30 m (km²)	19	194	48	53	3	4	4
SEA FLOOR AREA 30-150 m (km²)	3	49	37	9	2	2	3
BATHYMETRY 0-30 m (km²)	1	185	17	11	<1	2	2
BATHYMETRY 30-150 m (km²)	2	49	17	8	2	2	3
OPTICAL COVERAGE 0-30 m (km)	46	55	54	66	24	21	29
OPTICAL COVERAGE 30-150 m (km)	0	1	0	<1	2	1	0

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

Figure **28**. PRIA Land and Seafloor Area and Primary Data Coverage from CRCP 2011.

2.5.1.2 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 crustaceans 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 300 m isobath to the 700 m isobath (73 FR 70603, November 21, 2008). Table 4 shows the depths of geologic features, the occurrence of MUS EFH at that feature, and the availability of long-term monitoring data at diving depths.

Table 4. Occurrence of EFH by feature. 1PIBMHC

Feature	Summit Minimum Depth	Coral Reef/Crustaceans exc. Deepwater Shrimp	Bottomfish	Deepwater Shrimp	CRED Long Term Monitoring
Johnston Atoll	Emergent	✓	✓	✓	✓
Palmyra	Emergent	✓	✓	✓	✓
Kingman Reef	Emergent	✓	✓	✓	✓
Extensive banktop 80 km SW of Kingman		?	?	?	
Jarvis Island	Emergent	✓	✓	✓	✓
Howland Island	Emergent	✓	✓	✓	✓
Baker Island	Emergent	✓	✓	✓	✓
Southeast of Baker	?	?	?	✓	
Wake Island	Emergent	✓	✓	✓	✓
South of Wake	?	?	?	✓	

2.5.1.2.1 RAMP Indicators

Benthic percent cover of coral, macroalgae, and crustose coralline algae from CRED are found in the following tables. CRED 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 one 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 seastars, sea cucumbers, free and boring urchins, and giant clams).

Towed-diver surveys are typically 50 min long and cover about two to three 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 5. Mean percent cover of live coral from RAMP sites collected from towed-diver surveys in the PRIA

	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015
Baker	35.37	49.47	38.78		32.95		41.2		47.44		42.1		34.48
Howland	29.06	42.53	36.75		34.69		44.47		50.74		43.26		23.2
Jarvis	24.22	26.19	30.63		28.54		27.7		26.92		25.38		39.75
Johnston			5.01		22.95		18.38		7.94		10.89		7.46
Kingman	39.77	49.51	38.35		24.59		33.13		35.56		37.11		41.92
Palmyra	24.95	31.99	35.07		22.66		25.02		35.35		31.11		42.77
Wake				31.98		19.29		22.56		31.4		32.34	

Table 6. Mean percent cover of macroalgae from RAMP sites collected from towed-diver surveys in the PRIA

	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015
Baker	12.33	2.11	12.63		9.29		8.09		1.6		8.05		2.15
Howland	2.58	5.34	13.01		3.57		6.14		0.64		6.07		1.08
Jarvis	28.75	10.88	25.03		38.14		24.01		7.35		7.58		3.94
Johnston			25.06		6.9		8.82		1.57		8.49		2.49
Kingman	4.36	5.36	27.04		7.81		7.31		3.97		5.05		2.04

Palmyra	13.28	10.45	23.14		15.17		11.98		4.76		8.94		4.35
Wake				22.88		18.74		12		8.3		6.8	

Table 7. Mean percent cover of crustose coralline algae from RAMP sites collected from towed-diver surveys in the PRIA

	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015
Baker	31.66	37.57	39.61		33.43		23.09		23.4		24.03		32.8
Howland	36.6	27.4	34.26		22.6		22.59		15.73		18.12		21.25
Jarvis	29.11	29.56	34.76		24.23		11.82		30.29		24.2		27.48
Johnston			30.54		19.5		16.07		17.13		17.49		17.45
Kingman	33.04	16.4	17.49		23.5		13.45		9.2		8.45		9.64
Palmyra	38.46	24.46	27.26		26.3		18.02		13.87		17.09		10.28
Wake				1.01		6.43		3.87		4.15		1.13	

2.5.1.3 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.

2.5.4 Report on Review of EFH Information

The precious corals biological components were reviewed through production of this annual report. The non-fishing impact and cumulative impacts components are scheduled for review in 2016. Precious corals information can be found in Attachment 2.

2.5.5 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:

1. Level 1: Distribution data are available for some or all portions of the geographic range of the species.
2. Level 2: Habitat-related densities of the species are available.
3. Level 3: Growth, reproduction, or survival rates within habitats are available.
4. 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. Each fishery section also includes the description of EFH, the 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. A section summarizing the annual review that was performed follows.

2.5.1.4 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 8. Level of EFH information available for the Western Pacific precious corals management unit species complex.

Species	**Pelagic phase (larval stage)**	**Benthic phase**
Pink Coral		
Corallium secundum	0	4
C. regale	0	2
C. laauense	0	2
Gold Coral		
Gerardia spp	0	2
Callogorgia gilberti	0	2
Narella spp.	0	2

Species	Pelagic phase (larval stage)	Benthic phase
Bamboo Coral		
Lepidisis olapa	0	2
Acanella spp.	0	2
Black Coral		
Antipathes dichotoma	0	4
A. grandis	0	4
A. ulex	0	2

2.5.1.5 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 9. Level of EFH information available for the Western Pacific 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
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

2.5.1.6 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 10. Level of EFH information available for the Western Pacific crustaceans 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

2.5.1.7 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 redesignating certain CREMUS into the ecosystem component classification. Ecosystem component species do not require EFH designations, as they are not a managed species.

2.5.6 Research and Information Needs

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

2.5.6.1 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

2.5.6.2 Bottomfish Fishery

- Inventory of marine habitats in the EEZ of the Western Pacific region
- Data to obtain a better SPR estimate for American Samoa’s bottomfish complex

- Baseline (virgin stock) parameters (CPUE, percent immature) for the Guam/NMI deep-water and shallow-water bottomfish complexes
- High resolution maps of bottom topography/currents/water masses/primary productivity
- Habitat utilization patterns for different life history stages and species

2.5.6.3 Crustaceans Fishery

- Identification of post-larval settlement habitat of all CMUS
- Identification of “source/sink” relationships in the NWHI and other regions (ie, 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 NMI
- High resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, habitat relief

2.5.6.4 Precious Corals Fishery

- Distribution, abundance and status of precious corals in the Western Pacific.

2.5.7 References

Annette DesRochers. “Benthic Habitat Mapping.” NOAA Fisheries Center, Honolulu, HI. Presentation. April 6, 2016.

Coral Reef Ecosystem Program; Pacific Islands Fisheries Science Center 2016. Benthic Percent Cover Derived from Analysis of Benthic Images Collected during Towed-diver Surveys of the U.S. Pacific Reefs Since 2003 (NCEI Accession <unassigned>). NOAA National Centers for Environmental Information. Unpublished Dataset. April 5, 2016.

Miller, J; Battista, T.; Pritchett, A; Rohmann, S; Rooney, J. Coral Reef Conservation Program Mapping Achievements and Unmet Needs. March 14, 2011. 68 p.

Pacific Islands Fisheries Science Center Ecosystem Sciences Coral Reef Ecosystem Survey Methods. Benthic Monitoring. http://www.pifsc.noaa.gov/cred/survey_methods.php. Updated April 1, 2016. Accessed April 5, 2016.

Pacific Islands Fisheries Science Center (2011) Coral reef ecosystems of American Samoa: a 2002–2010 overview. NOAA Fisheries Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-11-02, 48 p.

2.6 Marine Planning

2.6.1 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 incorporate marine planning in its actions began in response to Executive Order (EO) 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes, issued by President Barack Obama on June 19, 2010. EO 13547 adopted the recommendations of the Interagency Ocean Policy Task Force and directed executive agencies to implement those recommendations as the National Ocean Policy. A third of the Task Force document addressed marine planning.

In 2015, the Council adopted its Marine Planning and Climate Change (MPCC) Policy, drafted by the Council's MPCC Committee, to help it coordinate development and amendment of its fishery ecosystem plans, programs, and other relevant activities. The policy uses the definition of marine planning from the National Ocean Policy Implementation Plan. The MPCC policy recognizes a set of overarching and specific principles and specific policy points for the Council, its advisory bodies and its staff to consider and incorporate in the Pacific Remote Island Area (PRIA) Fishery Ecosystem Plan (FEP). Of the MPCC policy's overarching principles, three relate to marine planning. The MPCC policy recognizes marine planning as an appropriate approach to reconciling intersecting human use, ocean resource, and ecosystem health at multiple geographic scales. The MPCC policy also recognizes that traditional resource management systems, such as the ahupua`a system in Hawai`i and Fa`a Samoa in American Samoa can provide an appropriate context for marine planning. Lastly, the MPCC Policy states that marine protected areas (MPAs), a tool used in marine planning, can and should be used for climate change reference and human use and impact research.

In promoting the ecosystem approach to management, the Council will carefully consider the impact on fisheries and fishery resources, including traditional fisheries, resources, knowledge, and fishing rights when participating in marine planning for activities such as offshore energy development. A key component of the MPCC policy is collaboration with existing organizations in data and information collection, dissemination and outreach. The Council intends to work with the Pacific Islands Regional Planning Body (RPB), community members, the private sector, schools, policymakers and others in Hawai`i, American Samoa, Guam and the Commonwealth of the Northern Mariana Islands (CNMI). The MPCC Policy can be found on the Council's website.

The Council's Plan Team (restructured in 2015) includes a marine planning expert to oversee inclusion of marine planning in the annual report. The marine planning annual report attempts to bring together available data related to marine planning that are relevant to the Council's roles in marine planning on an annual scale. Marine planning concerns with timelines shorter than a year are not included in this report. These roles are:

1. Implementation of the Magnuson-Stevens Fishery Conservation and Management Act (MSA)
2. Implementation of the National Environmental Policy Act (NEPA)

3. Stakeholder in non-MSA planned ocean activities
4. Member of the Pacific Islands RPB

2.5.1.8 MSA and NEPA Implementation

Marine planning is relevant to the implementation of the MSA through:

- Responding to previous Council recommendations relevant to its marine planning role
- Monitoring achievement of FEP objectives
- Defining essential fish habitat (EFH) and EFH Information
- Working with the National Marine Fisheries Service (NMFS) Pacific Islands Regional Office (PIRO) to identify and provide conservation and enhancement recommendations on activities that may cause adverse effects to essential fish habitat (EFH), and
- Tracking any changes in the cumulative impact of fishing, non-MSA fishing, and non-fishing activities on EFH.

Similarly, NEPA requires federal agencies to analyze the cumulative impacts of their actions with past, present, and reasonably foreseeable future activities.

At its 165th meeting in March 2016, in Honolulu, Hawaii, 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:

a. 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.
b. Establish effective spatially-based fishing zones.
c. Consider modifying or removing spatial-based fishing restrictions that are no longer necessary or effective in meeting their management objectives.
d. 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. Non-Council MPAs are also reported on. Council research needs are identified and prioritized through the Five Year Research Priorities and other processes, and are not tracked in this report.

In order to meet the EFH and NEPA mandates, this annual report tracks activities that occur in the ocean that are of interest to the Council and incidents that may contribute to cumulative impact. While the Council is not responsible for NEPA compliance, monitoring the environmental effects of ocean activities for the FEP's EFH cumulative impacts section is duplicative of the agency's NEPA requirement, and therefore, this report can provide material or suggest resources to meet both mandates.

2.5.1.9 Stakeholder in Non-fishing Activities

Tracking activities also assists the Council in its role as a stakeholder in other offshore activities. In the Western Pacific Region, fisheries compete with other activities for access to and use of fishing grounds. These activities include, but are not limited to, military bases and training activities, commercial shipping, marine protected areas, recreational activities and off-shore energy projects. Between the Bureau of Ocean Energy Management (BOEM), the Army Corps of Engineers (USACE), and the National Marine Fisheries Service (NMFS), most permits for offshore energy development, dredging or mooring projects that occur in the waters of the US, and offshore aquaculture are captured. Department of Defense activities regarding military bases and training are assessed in environmental impact statements (EISs) on a five year cycle and include assessments of potential conflict with fisheries; the EISs are available through the Federal Register. Due to the sheer volume of ocean activities and the annual frequency of this report, only major activities on multi-year planning cycles or those permitted by NMFS Sustainable Fisheries Division are tracked in this report.

The Council may comment on actions of any type that interact with fisheries and fishing communities. The Council may specifically provide conservation and enhancement recommendations (MSA §305(b)(3)) on activities that may adversely affect EFH in coordination with or independently from the NMFS PIRO Habitat Conservation Division.

2.5.1.10 Member of the Pacific Islands Regional Planning Body

EO 13547 (July 22, 2010), Stewardship of the Ocean, Our Coasts, and the Great Lakes, established the National Ocean Council and among other things, directed “the development of coastal and marine spatial plans that build upon and improve existing Federal, State, tribal, local, and regional decision-making and planning processes.” The EO described the Pacific Islands (includes American Samoa, CNMI, Guam, and Hawaii) as one of nine regions where a regional planning body (RPB) would be established for development of a coastal and marine spatial (CMS) plan. The EO adopted the Final Recommendations of the Interagency Ocean Policy Task Force as the National Ocean Policy.

The Council is a member of the Pacific Islands (PI) 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 PI RPB. Section 0 contains a summary of the PI RPB progress to date in developing the CMS plan for the Pacific Islands region.

2.5.1.11 Organization of the Report

The annual report is organized by MMAs, activities, incidents that may contribute to cumulative impact, the RPB report, references, and finally a maps section.
Marine Managed Areas

2.6.1.1 MMAs established under FMPs

Council-established marine managed areas (MMAs) were compiled in Table 11 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. These marine managed areas are shown in the Spatial Management Areas Established under FMPs map in the maps section. There are no standing Council recommendations indicating review deadlines.

Table 11. MMAs established under FEPs from 50 CFR § 665.

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Other Restrictions								
Howland Island No-Take MPA/PRI Marine National Monument	PRIA/ Pelagic	Howland Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nmi	2013	-

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Jarvis Island No-Take MPA/PRI Marine National Monument	PRIA/ Pelagic	Jarvis Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nmi	2013	-
Baker Island No-Take MPA/PRI Marine National Monument	PRIA/ Pelagic	Baker Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nmi	2013	-

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Kingman Reef No-Take MPA/PRI Marine National Monument	PRIA/Pelagic	Kingman Reef	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; all fishing prohibited within 12 nmi	2013	-
Johnston Atoll Low-Use MPA/PRI Marine National Monument	PRIA/ Pelagic	Johnston Atoll	69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nmi in Am. 2	2013	-

Name	FEP	Island	50 CFR /FR /Amendment Reference	Marine Area (km^2)	Fishing Restriction	Goals	Most Recent Evaluation	Review Deadline
Palmyra Atoll Low-Use MPAs/PRI Marine National Monument	PRIA/ Pelagic	Palmyra Atoll	69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nmi in Am. 2	2013	-
Wake Island Low-Use MPA/PRI Marine National Monument	PRIA/Pelagic	Wake Island	69 FR 8336 Coral Reef Ecosystem FEP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nmi in Am. 2	2013	-

2.6.1.2 Other MPAs in the Region

Marine Protected Area (MPA) data were downloaded from the NOAA Marine Protected Areas Center Data Inventory. Data are current through 2014.

The Excel MPA Inventory was filtered to retain only those records without GIS data for the following management agencies: Bureau of Ocean Energy Management, Marine National Monuments, National Estuarine Research Reserve System, National Marine Fisheries Service, National Park Service, or National Wildlife Refuge System.

MPAs within the 200 nautical mile limit around Hawaii, American Samoa, Guam, the CNMI, Wake Island, Johnston Atoll, Palmyra Atoll and Kingman Reef, Jarvis Island, and Howland and Baker Islands were selected from the MPA GIS inventory and their attributes were exported to a spreadsheet. Fields that matched the Excel inventory were retained.

Type, size, location, and fishery measures are summarized in Table 12. MPAs are shown in the overview maps found in the map section.

Table 12. Marine Protected Areas in the Western Pacific Region from the MPA Inventory unless otherwise noted

Site ID	Name	State	Marine Area (km^2)	Fishing Restrictions
MNM8	Pacific Remote Islands Marine National Monument	Marine National Monuments	1,267,750.00	Commercial Fishing Prohibited, Recreational Fishing Restricted
NWR143	Johnston Island National Wildlife Refuge	National Wildlife Refuge System	2,202.78	Commercial and Recreational Fishing Prohibited
NWR157	Palmyra Atoll National Wildlife Refuge	National Wildlife Refuge System	2,051.73	Commercial Fishing Prohibited, Recreational Fishing Restricted
NWR190	Wake Atoll National Wildlife Refuge	National Wildlife Refuge System	2,027.38	Commercial Fishing Prohibited, Recreational Fishing Restricted
NWR145	Kingman Reef National Wildlife Refuge	National Wildlife Refuge System	1,968.05	Commercial and Recreational Fishing Prohibited
NWR59	Jarvis Island National Wildlife Refuge	National Wildlife Refuge System	1,756.62	Commercial and Recreational Fishing Prohibited
NWR53	Howland Island National Wildlife Refuge	National Wildlife Refuge System	1,688.47	Commercial and Recreational Fishing Prohibited
NWR10	Baker Island National Wildlife Refuge	National Wildlife Refuge System	1,663.16	Commercial and Recreational Fishing Prohibited
NMF215	Howland Island - no take MPA	National Marine Fisheries Service	-	Fishing Prohibited
NMF216	Jarvis Island - no take MPA	National Marine Fisheries Service	-	Fishing Prohibited

Site ID	Name	State	Marine Area (km^2)	Fishing Restrictions
NMF217	Baker Island - no take MPA	National Marine Fisheries Service	-	Fishing Prohibited
NMF218	Rose Atoll (American Samoa) - no take MPA	National Marine Fisheries Service	-	Fishing Prohibited
NMF219	Kingman Reef - no take MPA	National Marine Fisheries Service	-	Fishing Prohibited

2.6.2 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.

2.6.2.1 Aquaculture facilities

There are no offshore aquaculture projects in Federal waters, proposed or existing, in the PRIA.

2.6.2.2 Alternative energy facilities

There are no alternative energy facilities in Federal waters, proposed or existing, in the PRIA.

2.6.3 Incidents Contributing to Cumulative Impact

The Coast Guard and NOAA Office of Response and Restoration respond to marine pollution events related to vessels. The following table of incidents since 2011is from selected oil spills off US coastal waters and other incidents where NOAA's Office of Response and Restoration (OR&R) provided scientific support for the spill response (NOAA OR&R). These incidents are included in the overview maps of the map section. There were no incidents reported for the PRIA.

2.6.4 Pacific Islands Regional Planning Body Report

The Pacific Islands Regional Planning Body (PI RPB) will meet on March 30-31, 2016, to discuss a number of items. The PI RPB will be brought up to date on the planning activities in American Samoa and then will discuss how much participation the PI RPB would like to have in the development of the American Samoa Ocean Plan, given cross membership. The PI RPB will discuss its operations in the bigger context of efforts associated with climate change, planning efforts, and GIS efforts, as well as discuss a capacity assessment to inform the needs of the PI RPB. PI RPB members will then discuss their data and tools needs, as well as their stakeholder engagement progress.

The American Samoa Ocean Planning Team is meeting on March 28, 29, and April 1, 2016, to finalize their vision for the ocean in American Samoa and develop draft goals and objectives for their ocean plan.

2.6.5 References

Emergency Response Division, Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration 2016. Raw Incident Data. Dataset. March 1, 2016. Downloaded from http://incidentnews.noaa.gov/raw/index.

"Fisheries in the Western Pacific." Title 50 *Code of Federal Regulations*, Pt. 665. Electronic Code of Federal Regulations data current as of March 16, 2016. Viewed at http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b28abb7da3229173411daf43959fcbd1&n=50y13.0.1.1.2&r=PART&ty=HTML#_top.

"Fisheries Off West Coast States and in the Western Pacific; Coral Reef Ecosystems Fishery Management Plan for the Western Pacific, Final Rule." *Federal Register* 69 (24 February 2004): 8336-8349. Downloaded from http://www.wpcouncil.org/precious/Documents/FMP/Amendment5-FR-FinalRule.pdf.

National Marine Protected Areas Center; National Oceanic and Atmospheric Administration 2014. Marine Protected Areas Inventory. Dataset. January 15, 2016. Downloaded from http://marineprotectedareas.noaa.gov/dataanalysis/mpainventory/.

National Marine Protected Areas Center; National Oceanic and Atmospheric Administration 2014. Marine Protected Areas Inventory GIS Spatial Data. Dataset. January 15, 2016. Downloaded from http://marineprotectedareas.noaa.gov/dataanalysis/mpainventory/.

"Pelagic Fisheries of the Western Pacific Region, Final Rule." *Federal Register* 56 (18 October 1991): 52214-52217. Downloaded from http://www.wpcouncil.org/pelagic/Documents/FMP/Amendment3-FR-FinalRule.pdf.

"Pelagic Fisheries of the Western Pacific Region, Final Rule." *Federal Register* 57 (4 March 1992): 7661-7665. Downloaded from http://www.wpcouncil.org/pelagic/Documents/FMP/Amendment5-FR-FinalRule.pdf.

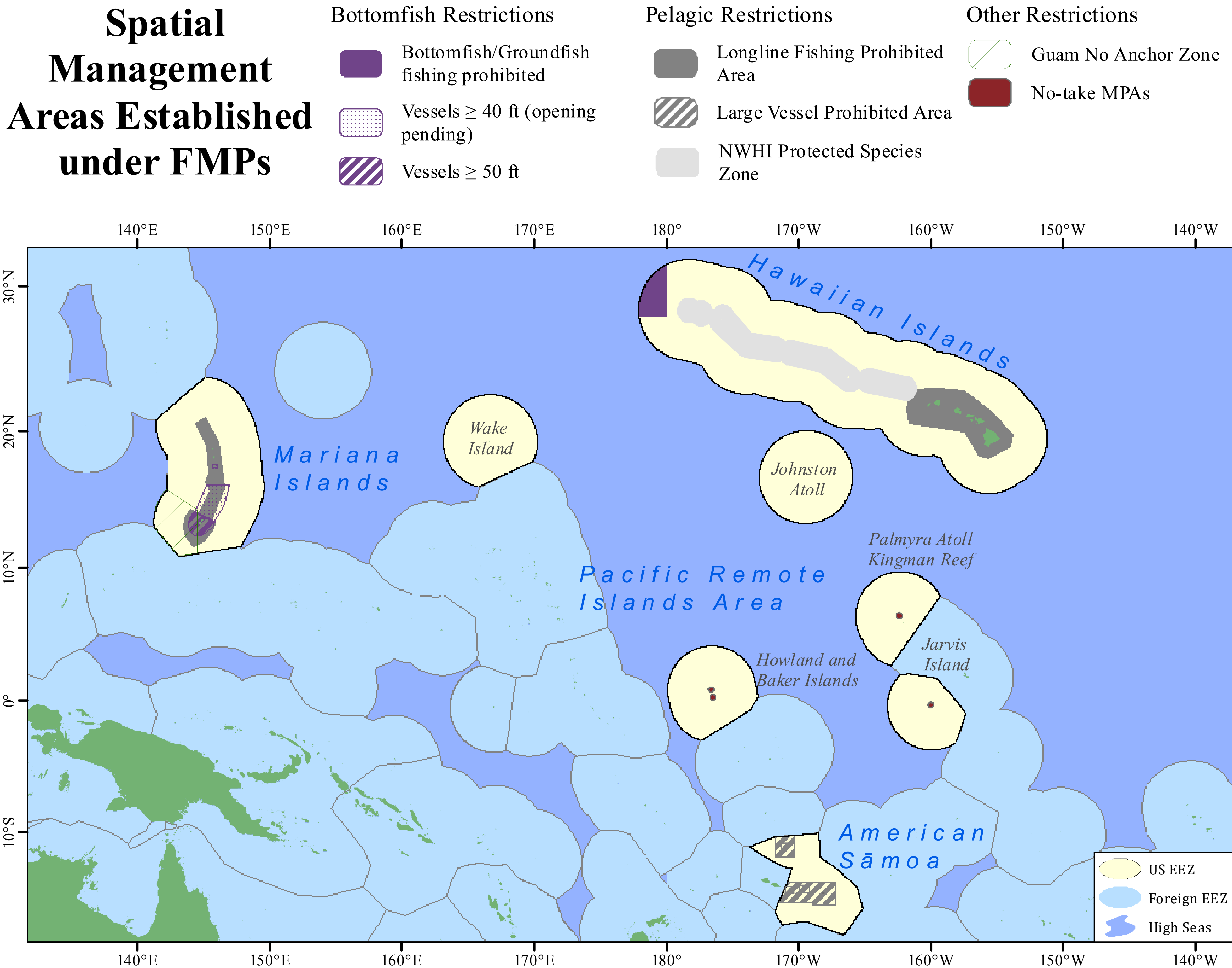
"Western Pacific Fisheries; Fishing in the Marianas Trench, Pacific Remote Islands, and Rose Atoll Marine National Monuments, Final Rule." *Federal Register* 78 (3 June 2013): 32996-33007. Downloaded from http://www.wpcouncil.org/precious/Documents/FMP/Amendment5-FR-FinalRule.pdf.

Western Pacific Regional Fishery Management Council. Fishery Management Plan and Fishery Ecosystem Plan Amendments available from http://www.wpcouncil.org/.

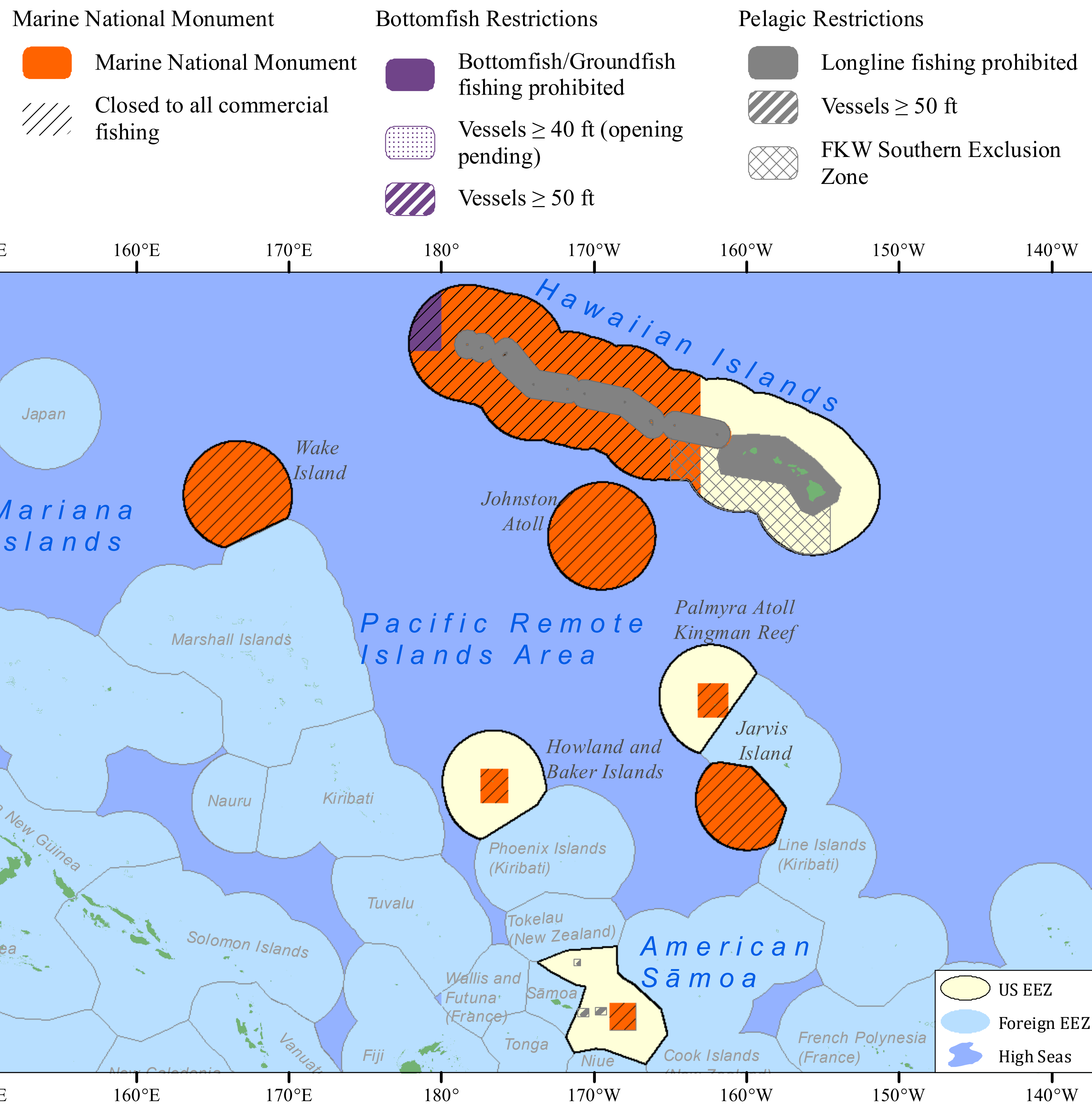
2.6.6 Maps

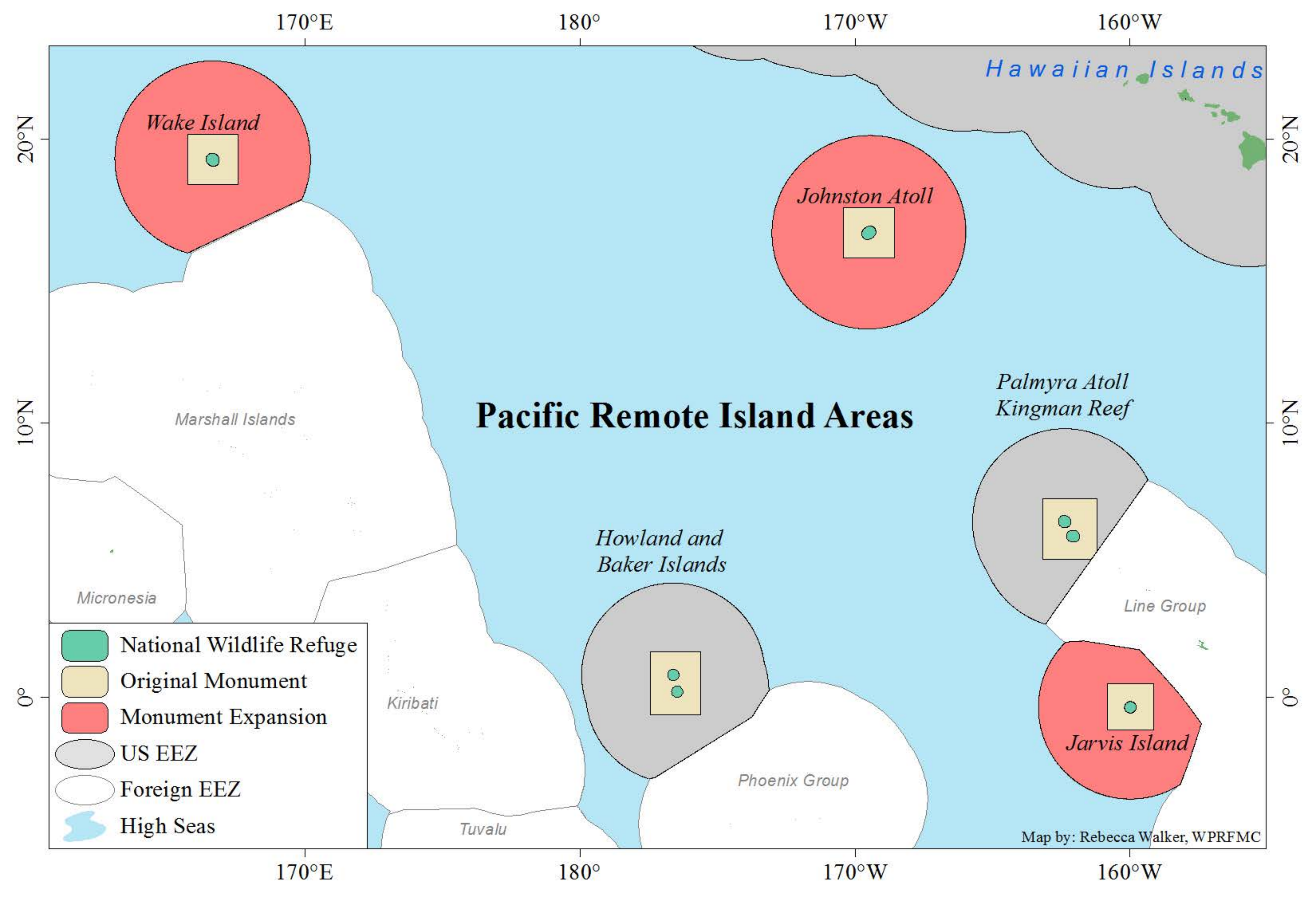
1. Spatial Management Areas Established under FMPs
2. Large, Regulated Commercial Fishing Areas of the Western Pacific Region
3. Pacific Remote Island Area Refuges and Monuments

Spatial Management Areas Established under FMPs



Large, Regulated Commercial Fishing Areas of the US EEZ, Western Pacific Region





170°E
180°
170°W
160°W
20°N
10°N
0°
Hawaiian Islands
Wake Island
Johnston Atoll
Pacific Remote Island Areas
Palmyra Atoll
Kingman Reef
Marshall Islands
Howland and
Baker Islands
Micronesia
Line Group
Kiribati
Jarvis Island
Phoenix Group
Tuvalu
National Wildlife Refuge
Original Monument
Monument Expansion
US EEZ
Foreign EEZ
High Seas
Map by: Rebecca Walker, WPRFMC

3 DATA INTEGRATION

The data integration chapter will be completed as resources allow.

Attachment 1: Report to the Plan Team

Process Options for Designation of Habitat Areas of Particular Concern
April 11, 2016
Ala Moana Hotel

Background

In 2014 and 2015, the Western Pacific Regional Fishery Management Council (Council) underwent a five year review of its Fishery Ecosystem Plans (FEPs) and management process. Through this process, the Council, its staff, and stakeholders identified areas for change and update of its plans. Essential Fish Habitat (EFH) was an area identified for update and review. The EFH Final Rule[1] strongly encourages Councils to review the EFH information included in fishery management plans on a five year cycle[2]. This report considers the last component of EFH information identified in the EFH Final Rule: the EFH update and review procedure.

The Council recommended that new EFH information be reviewed, as necessary, during preparation of the annual reports by the Plan Teams. EFH designations may be changed under the FEP framework processes if information presented in an annual review indicates that modifications are justified[3]. Habitat Areas of Particular Concern (HAPC) are a subset of the EFH designations. The FEPs do not provide explicit direction in how the Council will designate HAPCs.

According to the EFH Final Rule, Councils may designate HAPCs based on one of the four following considerations:

(i) The importance of the **ecological function** provided by the habitat.
(ii) The extent to which the habitat is **sensitive** to human-induced environmental degradation.
(iii) Whether, and to what extent, development activities are, or will be, **stressing** the habitat type.
(iv) The **rarity** of the habitat type.[4]

While an HAPC designation process is not required, it may focus review efforts and increase consistency, transparency, and defensibility in the implementation of the EFH provisions of the Magnuson-Stevens Act in the Western Pacific Region. The 2015 Plan Team took up the question of how the Council should designate HAPC. They were presented with the following four process options:

1. Continue to address HAPC on a case-by-case basis as issues arise.
2. Consider clarifying the Coral Reef HAPC language only, which suggests designation of previously existing MPAs as HAPC.

[1] 67 FR 2376, Jan. 17, 2002
[2] 50 CFR §600.815(a)(10)
[3] Please see Chapter 6 of any FEP developed by the Western Pacific Fishery Management Council.
[4] 50 C.F.R. 600.815(a)(7)

3. Modify and adopt the process used in the Hawaiian Archipelago bottomfish EFH review.
4. Create a new process through which HAPC candidates areas can be identified and filtered.

The Plan Team formed a working group to explore the options for this process, which was performed through two webinars facilitated by Council staff. The members of the working group were Samuel Kahng (Hawai`i), Brent Tibbats (Guam), Mike Tenorio (CNMI), Mareike Sudek/Domingo Ochavillo (American Samoa), with support from Danielle Jayewardene, Mathew Dunlap, and Michael Parke (NMFS). The findings are reported below.

Working Group Sessions
On the first call on September 2, 2015, working group participants heard a background on the Western Pacific's EFH and HAPC designations, and reviewed the HAPC designation processes used by other Councils. Participants reviewed the options presented to the 2015 Plan Team, discussed if any options should be added, and selected options to address in further detail on the next call. The following three options were chosen for further development:

- No Action, i.e. address HAPC on a case-by-case basis
- Adopting the Hawaiian Archipelago bottomfish EFH review model
- Creating a New Process

The second option, modifying the coral reef language, was rejected from further development. Language in the FEPs is not prescriptive of how coral reef HAPCs will be designated in the future, and therefore does not speak to the HAPC designation process. Concerns were expressed that designating HAPCs based on existing protective status can create overly broad HAPC designations and does not necessarily effectively meet the intent of HAPC designation as per the EFH final rule. Additionally, the Council at its 163rd meeting directed staff to further explore and provide the Council with details in improving the ACL specification process through an omnibus amendment of the Fishery Ecosystem Plans to include, among other item, reclassification of appropriate management unit species into ecosystem components. As EFH does not need to be designated for species listed as ecosystem components, it would be most effective to address coral reef EFH once the ecosystem component species amendment is further developed.

Participants on the first call identified that a successful HAPC designation process would:

- be realistically implementable;
- effectively use the expertise in the region;
- be compatible with jurisdictional management;
- encourage the development of usable HAPC candidate area proposals; and
- occur within a reasonable amount of time.

Based on the first call, Council staff split the HAPC designation process into five separate components: the HAPC designation proposal development phase, the HAPC designation proposal review phase, development of a policy on weighting of HAPC considerations, standardizing the interpretation of the HAPC considerations, and timing for the HAPC designation process (Figure 4). A new process would involve some or all of these components; the bottomfish model for example included all components.

During a second call on November 23, 2015 , participants discussed the pros and cons of options for each of five components to evaluate each HAPC designation process.

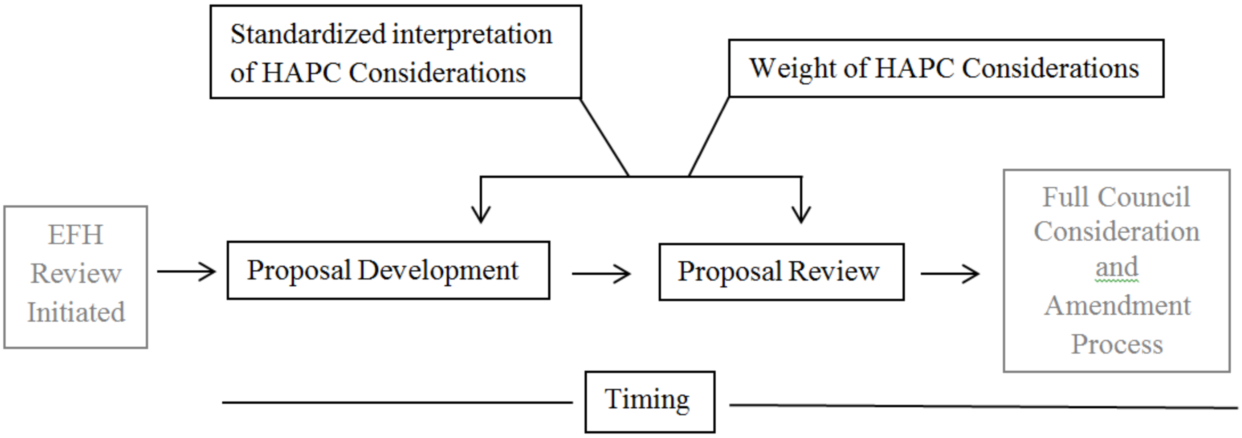


Figure 1. HAPC process components evaluated by the working group. The Council process is included for context.

Evaluation of HAPC Process Components

1. *Proposal Development Options*

During the proposal development phase**,** the participants agreed that it is key to identify a party who has the responsibility, dedication, expertise, and manpower to accomplish the task of submitting HAPC proposals. An option would be to develop and award service contracts, including for a graduate student, to develop proposals. Contractors would be dedicated to the effort, however acquiring funding for EFH review focused work is an ongoing challenge also requires management of the contract. Additionally, stakeholder involvement can be challenging when proposals are developed by contractors outside the Council process. A second option discussed was for fishermen, who are a key stakeholder group with specialized knowledge of habitat, to develop proposals. However, fisherman constitute only one stakeholder group so may not provide a broad enough perspective. The third option for proposal developers could be the general public.as they would give access to more experts and have increased stakeholder involvement. However according to the experience of other Councils, this approach presents a real risk of an unmanageable number of HAPC proposals being developed that may be irrelevant or incongruent with the Council's management objectives[5]. A fourth option was to have the Council's plan team develop proposals as they have the responsibility for the EFH review already in place. The concern with this approach is that plan team membership may change, and there may not be enough time dedicated in the process to develop supporting rationale for candidate areas. Finally, other Council bodies had the same pros and cons with the exception that the Plan Team is specifically responsible for the EFH review.

Finding

Plan Team members or their staff, and/or contractors seem the most reasonable entities to develop HAPC proposals, i.e. identify candidate HAPC areas for the Council's consideration in

[5] Habitat Working Group of the Council Coordinating Committee , Group Discussion, October 3, 2014

updating FEPs. Use of contractors allows flexibility when additional funding opportunities are available. When candidate HAPCs areas are identified outside the Council process, which would be the case with a contractor, the contract must be carefully managed to ensure the proposal addressed Council priorities and objectives and stakeholders are involved.

2. *Proposal Review Options*

In the proposal review phase, participants discussed the importance for the Pacific Island Fisheries Science Center (PIFSC) stock assessment authors to weigh in on the review of proposals for their stocks. Time management was the leading concern for Council staff and Advisory Panel review of the proposals. In the North Pacific region, Council staff review HAPC proposals to ensure consistency with Council priorities.[6] Advisory Panel review, however, would increase stakeholder participation in the HAPC designation process in the fishing community. This was considered an essential lesson learned from the Hawaiian Archipelago bottomfish EFH review. The Scientific and Statistical Committee (SSC) was recognized as the responsible body for review of all scientific information, and therefore HAPC proposals. The SSC is familiar with the fisheries, giving it an advantage over Center for Independent Expert (CIE) reviews. CIE reviews are managed at PIFSC.

Western Pacific Stock Assessment Review (WPSAR) is an existing peer review procedure for the scientific information that may be used as a basis for federal fisheries management in the region. A WPSAR review would occur as supplemental to the SSC's review, but may slow down the process. The WPSAR Coordinating Committee anticipates what WPSAR reviews may be needed for the region and advises the Steering Committee. The Steering Committee prioritizes and schedules regional science products for review based on its potential influence, available resources, and other factors as appropriate. Due to the implications stock assessments have on setting Annual Catch Limits, the assessments usually get higher priority than other scientific information like EFH or HAPC reviews. An HAPC proposal may be considered by the Steering Committee for the WPSAR schedule through two avenues: recommendation of the Coordinating Committee, or recommendation of the SSC.

Overall, interim checkpoints and the review methodology are important to ensure enough stakeholder involvement without prolonging the process. More levels of review mitigates the risk of rejection by various stakeholders, which may prolong the timeline of the review substantially.

Finding

Flexibility in the process is again important, so that as many reviewers may be exposed to the draft HAPC proposal without unnecessarily prolonging the process. Because the level of review is anticipated to be different for different managed fisheries, a concurrent initial review by Council staff, the PIRO regional EFH Coordinator, and Plan Team Habitat team members as well as the relevant PIFSC stock assessment authors will help to focus further review of the HAPC proposals through the Council process. These desktop reviewers will review the draft for scientific quality and consistency with Council objectives. The reviewers may make recommendations for additional stakeholder meetings if necessary. Comments should be

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[6] HAPC Process Document, North Pacific Fishery Management Council and National Marine Fisheries Service, Alaska Region. September 2010.

provided within 45 days to prevent delays in the review process. A flow chart depicting how the review process is integrated with the Council process is shown in Figure 5.

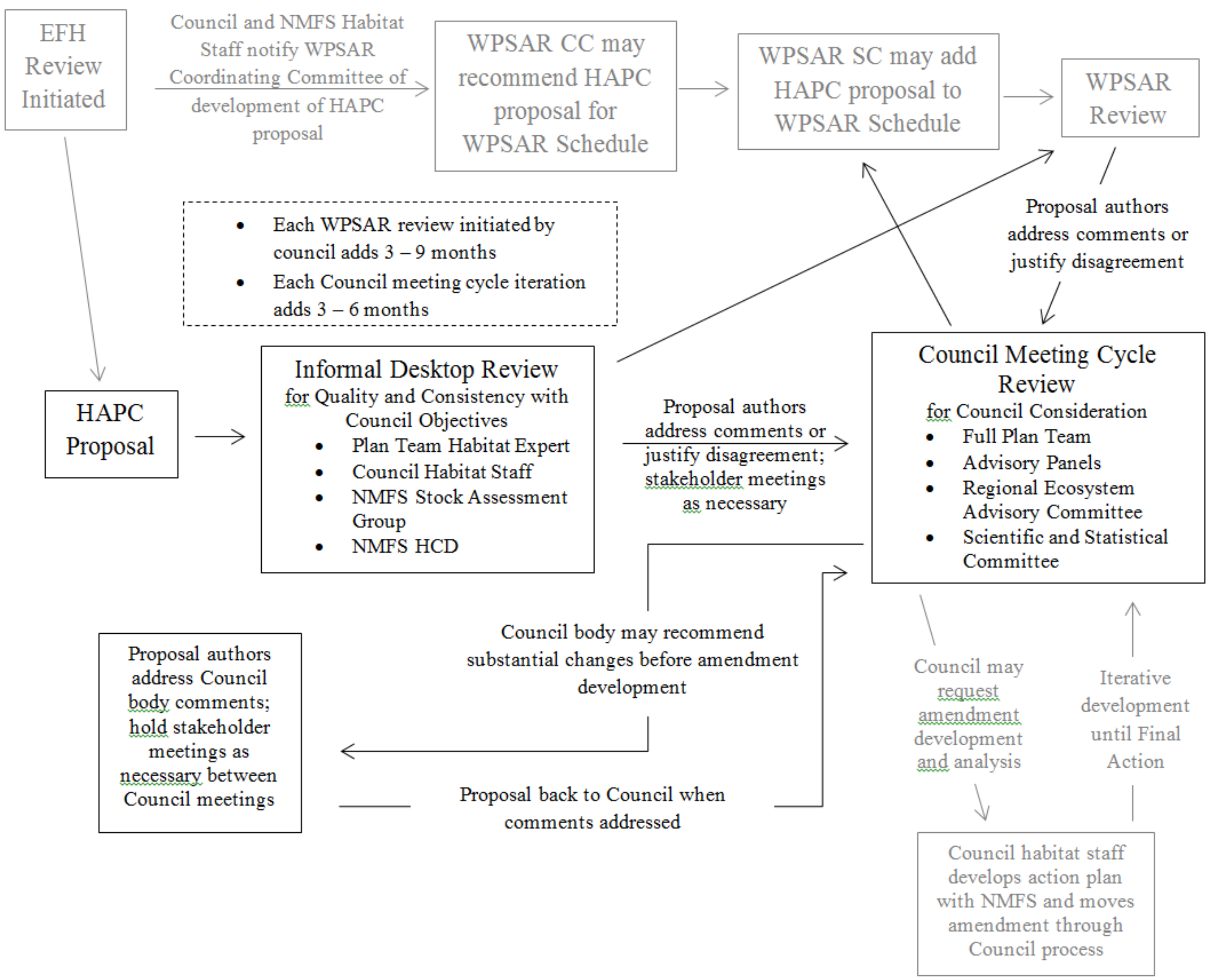

Figure 2. Integration of HAPC Proposal Review with the Council process. HAPC-specific phases are in black while established Council processes are in gray.

3. Weighting of HAPC Considerations

The working group discussed the weighting of considerations. In the WPSAR review of the bottomfish candidate areas, the panel determined that all candidate HAPCs must be ecologically important and meet one additional consideration in order to become an HAPC. The working group recognized that if the weighting is left up to the proposal writers or reviewers, the result could be subjective. Without any consideration of weighting, there are fewer restrictions on the proposal process and less quality control built into the process. However, the working group did not feel that recommending particular weights for the considerations was appropriate at this time, as some of the concerns with having no weighting for the considerations could be alleviated through developing terms of reference for candidate HAPC proposals.

4. Interpretation of Considerations

Further interpreting the considerations for the region had similar pros and cons as weighting the considerations. Interpreting them for the region may result in a more objective process, but runs the danger of producing overly restrictive proposals. Other Councils have interpreted the HAPC considerations further than in the EFH Final Rule, such as the North Pacific. This may be more appropriate in other regions that do authorize fishing gears with substantial adverse effects on EFH, where HAPC has been associated with gear closures. However, the Western Pacific Council does not authorize these gear types.

The working group did discuss the interpretation of the third consideration: “Whether, and to what extent, development activities are, or will be, stressing the habitat type.” Participants agreed that local or regional actions/ threats should be given more consideration than global threats when the stressor/s associated with the global threats are not identifiable at a habitat and/or site specific scale.

Findings

The primary purpose of further interpreting and weighting the HAPC considerations is to increase the quality and refine the HAPC candidate areas received in a proposal. Terms of reference for the development of HAPC proposals could address these goals, while involving members of other Council bodies that are more appropriate for policy, not FEP, development.

Proposed HAPC Process and Recommendations

The working group recommends to the Plan Team that Council staff develop an HAPC policy from the working group discussions. The policy should include terms of reference for proposals from the HAPC guidance documents, working group discussions, and additional input from other relevant sources including Council bodies. If contractors are used to identify candidate areas, a term of the contract must be to gather information from the Council’s advisory bodies and NMFS before submitting a final proposal for review to the Plan Team, Scientific and Statistical Committee, Advisory Panels, and Council. In addition to the regular Council process and WPSAR process, the HAPC process will include an initial desktop review of the HAPC proposal by Council habitat staff and Plan Team member, stock assessment scientists from the PIFSC Stock Assessment group, and NMFS Habitat Conservation Division. Producing a policy, instead of amending the FEPs with an HAPC update procedure, will facilitate flexibility in the process by not requiring a new amendment for revision of the process.

ATTACHMENT 2: DRAFT Precious Corals Species Descriptions Update

1 PRECIOUS CORALS SPECIES

1.1 General Distribution of Precious Corals

This document is an update of the 2015 "Essential Fish Habitat Source Document for Western Pacific Archipelagic, Remote Island Areas, and Pelagic Fishery Ecosystem Plan Management Unit Species" for precious corals. Important new references and data points have been added to the original documentation. Many older observations continue to be cited because no newer studies have been completed, with a few notable exceptions. While the original sources are still relevant, new research has revealed important distribution, life history, growth rate, age, and abundance information that is relevant to precious coral management. Some progress has also been made toward clarifying some of the vexing taxonomic challenges presented by these organisms. First, the name of the most important species of gold coral, *Gerardia* sp., has been updated to *Kulamanamana haumeaae* by Sinniger, *et al.* (2013). Second, two of the most important species in the family Coralliidae, *Corallium secundum* (pink coral) and *Corallium regale* (red coral) have been placed into separate genera, the latter also becoming a different species (Figueroa & Baco, 2014). Their new names are now *Pleurocorallium secundum* and *Hemicorallium laauense*, respectively. Third, two changes have taken place in the black corals. *Antipathes dichotoma* is now *Antipathes griggi* and *Antipathes ulex* has been moved to a different genus and is now *Myriopathes ulex* (Opresko, 2009). These changes are shown in Table 1.

Most research related to precious corals has been limited to the Hawaiian archipelago, and the majority of the more recent efforts have been directed at taxonomy or simply documenting species distributions, with a few works on growth and life history (*Parrish et al.*, 2015). However, significant new insights have been gained into the genetics (Baco and Cairns, 2012; Sinniger, *et al*., 2013; Figueroa and Baco, 2014), reproductive biology (Waller and Baco, 2007; Wagner, *et al.*, 2011; Wagner *et al.*, 2012; Wagner *et al.*, 2015), growth and age (Parrish and Roark 2009; Roark *et al.*, 2009), and community structure (Kahng *et al*., 2010; Long and Baco, 2014; Parrish, 2015; Wagner, *et al*., 2015) of precious coral and black coral species.

The U.S. Pacific Islands Region under jurisdiction of the Western Pacific Regional Fisheries Management Council consists of more than 50 oceanic islands, including the Hawaiian and Marianas archipelagos, American Samoa, Johnston, Wake, Palmyra, Kingman, Jarvis, Baker and Howland, and numerous seamounts in proximity to each of these groups. These islands fall under a variety of political jurisdictions, and include the State of Hawaii, the Commonwealth of the Northern Mariana Islands (CNMI), and the territories of Guam and American Samoa, as well as nine sovereign Federal territories—Midway Atoll, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland Island, Baker Island, Rose Atoll, and Wake Island. Precious corals (with currently accepted species names) are known to exist in American Samoa, Guam, Hawaii and the Northern Mariana Islands, as well as throughout the other US islands in the Pacific (Tables 1 and 2), but the only detailed assessments of precious corals have been in Hawaii (Parrish and Baco, 2007, Parrish *et al*., 2015; Wagner, *et al*., 2015). Over the last 10 years, we have begun to better understand the distribution and abundance of these corals, but many areas remain unexplored, and conditions which lead to their settlement, growth and distribution are still uncertain. Modelling efforts have provided some insight into the global distribution and habitat requirements of deep-water corals (Rogers *et al.*, 2007; Tittensor *et al.*, 2009, Clark *et al.*, 2011, Yesson *et al.*, 2012, Schlacher *et al.*, 2013), but have provided little certainty regarding localized distribution or the specific conditions required for growth of precious corals. Antipatharians, commonly known as black corals, have been exploited for years, but are still among the taxonomic groups containing precious corals that have been inadequately surveyed, as evidenced by the high rates of species discoveries from deep-water surveys around the Hawaiian Islands (Opresko 2003b; Opresko 2005a; Baco 2007; Parrish & Baco 2007; Parrish *et al.*, 2015; Roark, 2009; Wagner *et al.*, 2011, 2015; Wagner, 2011, 2013). Despite this ongoing research, only a few places are known to have dense agglomerations of precious corals. A summary of the known distribution and abundance of precious corals in the central and western Pacific Islands region follows.

Table 1: Precious corals covered under the FMP

Species	Common name
Pleurocorallium secundum (prev. *Corallium secundum*)	Pink coral
Hemicorallium laauense (prev. *C. regale*)	Red coral
Kulamanamana haumeaae (prev. *Gerardia* sp.)	Gold coral
Narella sp.	Gold coral
Calyptrophora sp.	Gold coral
Callogorgia gilberti	Gold coral
Lepidisis olapa	Bamboo coral
Acanella sp.	Bamboo coral
Antipathes griggi (prev. *A. dichotoma)*	Black coral
Antipathes grandis	Black coral
Myriopathes ulex (prev. *Antipathes ulex*)	Black coral

American Samoa

There is little information available for the deepwater species of precious corals in American

Samoa. Much of the information available comes from the personal accounts of fishermen. In the South Pacific there are no known commercial beds of pink coral (Carleton and Philipson 1987). Survey work begun in 1975 by the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) identified three areas of *Corralium* off Western Samoa: off eastern Upolu, off Falealupo and at Tupuola Bank (Carleton and Philipson 1987). Pink coral has been reported off Cape Taputapu, but no information concerning the quality or quantity of these corals or the depths where they occur is available. Unidentified precious corals have also been reported in the past off Fanuatapu at depths of around 90 m. Precious corals are known to occur at an uncharted seamount, about three-fourths of a mile off the northwest tip of Falealupo Bank at depths of around 300 m.

Commercial quantities of one or more species of black coral are known to exist at depths of 40 m and deeper. However, these are found in the territorial waters of American Samoa and, therefore, are not subject to the Council's authority. Wagner (personal communication, 2015) has tentatively identified as many as 12 species (not previously catalogued in Am. Samoa) of black corals in depths between 50m and 90m, with 6 of these potential new species exhibiting growth forms that could lead to harvestable sizes. However, Wagner did not see find any locations with the types of densities and sizes that would support any commercial harvest of these corals.

<u>Guam and the Commonwealth of the Northern Marianas</u>

There are no known commercial quantities of precious corals in the Northern Mariana Islands archipelago (Grigg and Eldredge 1975). In the past, Japanese fishermen claimed to have taken some *Corralium* north of Pagan Island and off Rota and Saipan. Surveys are planned for the Marianas Islands in 2016 that may provide more information regarding abundance and distribution of certain precious corals found in waters deeper than 250 m.

<u>U.S. Pacific Island Remote Areas</u>

There are no known commercial quantities of precious corals in the remote Pacific Island areas, though individual colonies of precious corals have been seen at Jarvis, Palmyra, Kingman (Parrish and Baco, 2007) and Johnston Atoll, and planned surveys in 2017 may provide more information about abundance and distribution of precious corals found in waters deeper than 250 meters in these areas.

<u>Hawaii</u>

In the Hawaiian Archipelago there are seven legally-defined beds of pink, gold and bamboo corals, which are shown in Table 2. It is difficult to determine from the publication record exactly why these particular areas were singled out for legal recognition, other than the fact that they contain some unspecified densities of precious corals within their geographic boundaries. In the MHI, the Makapuu bed is located off Makapuu, Oahu, at depths of between 250 and 575 meters. Discovered in 1966, it the precious coral bed that has been most extensively surveyed in the Hawaiian chain. Its total area is about 4.5 km^2. Its substrate consists largely of hard limestone (Grigg, 1988). Careful examination during numerous dives with a submersible has determined that about 20% of the total area of the Makapuu bed is comprised of irregular lenses of thin sand, sediments and barren patches (WPRFMC, 1979). These sediment deposits are found primarily in low lying areas and depressions (Grigg, 1988). Thus, the total area used for extrapolating coral density is 3.6 km^2, or 80% of 4.5 km^2 (WPRFMC, 1979).

Precious coral beds have also been found in the deep inter-island channels such as Auau, Alalakeiki, and Kolohi channels off of Maui, around the edges of Penguin Banks, off promontories such as Keahole Point, on older lava flows south from Keahole to Ka Lae, and off of Hilo Harbor, and off of Cape Kumukahi on the Big Island of Hawaii (Oishi, 1990; Grigg, 2001, 2002). On Oahu, there is a bed off Kaena Point, and multiple precious coral observations have been made from offshore Barber's Point extending to offshore Pearl Harbor, Oahu. On Kauai, a bed of black corals has been identified offshore of Poipu (WPRFMC, 1979).

A dense bed has been located on the summit of Cross Seamount, southwest of the island of Hawaii. This bed covers a pinnacle feature on the top of the summit, but does not contain numbers of corals large enough to sustain commercial harvests (Kelley, pers. comm., 2015).

Table 2: Location of legally-defined precious coral beds. Source: WPRFMC 1979

Area Name	**Description**
Makapu'u (Oahu)	**includes the area within a radius of 2.0 nm of a point at 21°18.0′ N. lat., 157°32.5′ W. long.**
Auau Channel, Maui	**includes the area west and south of a point at 21°10′ N. lat., 156°40′ W. long., and east of a point at 21° N. lat., 157° W. long., and west and north of a point at 20°45′ N. lat., 156°40′ W. long.**
Keahole Point, Hawaii	**includes the area within a radius of 0.5 nm of a point at 19°46.0′ N. lat., 156°06.0′ W. long.**
Kaena Point, Oahu	**includes the area within a radius of 0.5 nm of a point at 21°35.4′ N. lat., 158°22.9′ W. long.**
Brooks Banks	**includes the area within a radius of 2.0 nm of a point at 24°06.0′ N. lat., 166°48.0′ W. long.**
180 Fathom Bank, north of Kure Island	**N.W. of Kure Atoll, includes the area within a radius of 2.0 nm of a point at 28°50.2′ N. lat., 178°53.4′ W. long.**
WesPac Bed, between Nihoa and Necker Islands	**includes the area within a radius of 2.0 nm of a point at 23°18′ N. lat., 162°35′ W. long. ***

* This area falls within the boundaries of the Papahanaumokuakea National Marine so

precious corals here are no longer subject to harvest or removal.
In the NWHI, a small bed of deepwater precious corals have been found on WestPac bed, between Nihoa and Necker Islands and east of French Frigate Shoals. This bed is not large enough to sustain commercial harvests. Precious coral beds have also been discovered at Brooks Banks, Pioneer Bank, Bank 8, Seamount 11, Laysan, and French Frigate shoals (Parrish and Baco, 2007; Parrish *et al*., 2015). ROV surveys conducted throughout the NWHI by the Okeanos Explorer during 2015 discovered multiple places that had dense colonies of deep-sea corals. Few of these colonies were precious corals, but these dives were mostly conducted in waters deeper than normal distributions of precious corals (>1500 meters). However, large areas of potential habitat exist in the NWHI on seamounts and banks near 400 m depth. Based on the abundance of potential habitat, it is thought that stocks of precious corals may be more abundant in the northwestern end of the island chain. All precious coral stocks within the boundaries of the Paphanaumokuakea National Marine Monument are protected from harvest, and most habitat suitable for precious corals growth falls within the boundaries of the monument.

Precious corals have also been discovered at the 180 Fathom Bank, north of Kure Island. The extent of this bed is not known. Precious corals have been observed during submersible and ROV dives throughout the Northwestern Hawaiian Islands, and in EEZ waters surrounding Johnston, Jarvis, Palmyra, and Kingman atolls, but little can be definitively said about the overall distribution and abundance of precious corals in the central Pacific region.

In addition to these legally defined areas of precious corals, many other sites have been discovered that sustain populations of precious corals (Parrish and Baco, 2007; Parrish *et al*., 2015; Wagner *et al*., 2015). The map below (Figure 1) provides a color-coded illustration of some of these 8600 observations (Kelley and Drysdale, 2012, *unpublished data*). Given the number of observations and the wide distribution of precious corals in the main Hawaiian Islands, it is almost certain that undiscovered beds of precious corals exist in the EEZ waters of the region managed by the WPRFMC. Whether these beds would contain organisms at sufficient densities and size distributions to support commercial harvests is yet to be determined.

1.2 Systematics of the Deepwater Coral Species

Published records of deep corals from the Hawaiian Archipelago include more than 137 species of gorgonian octocorals and 63 species of azooxanthellate scleractinians (Parrish and Baco, 2007). A total of 6 new genera and 20 new species of octocorals, antipatharians, and zoanthids have been discovered in Hawaii since the 2007 report (Parrish *et al.*, 2015). These are either new to science, or new records for the Hawaiian Archipelago (Cairns & Bayer 2008, Cairns 2009, Opresko 2009, Cairns 2010, Wagner *et al.*, 2011a, Opresko *et al.*, 2012, Sinniger *et al.*, 2013). Taxonomic revisions currently underway for several groups of corals, e.g., isidids, coralliids, plexaurids and paragorgiids, are also likely to yield additional species new to science and new records for Hawaii (Parrish *et al.*, 2015). Only a handful of these deep coral species are considered economically *precious* and have any history of exploitation.

Recent molecular phylogenetic and morphologic studies of the family Coralliidae, including Hawaiian precious corals, have illuminated taxonomic relationships. These studies synonymized

Paracorallium into the genus Corallium, and resurrected the genera Hemicorallium (Ardila *et al*., 2012; Figueroa & Baco, 2014; Tu *et al*., 2015) and Pleurocorallium (Figueroa & Baco, 2014; Tu *et al*.,2015) for several species, including several species in the precious coral trade. A molecular and morphological analysis of octocoral-associated zoanthids collected from the deep slopes in the Hawaiian Archipelago revealed the presence of at least five different genera including the gold coral (Sinniger *et al*.,2013). This study describes the five new genera and species and proposes a new genus and species for the Hawaiian gold coral, *Kulamanamana haumeaae*, an historically important species harvested for the jewelry trade and the only Hawaiian zoanthid that appears to create its own skeleton.

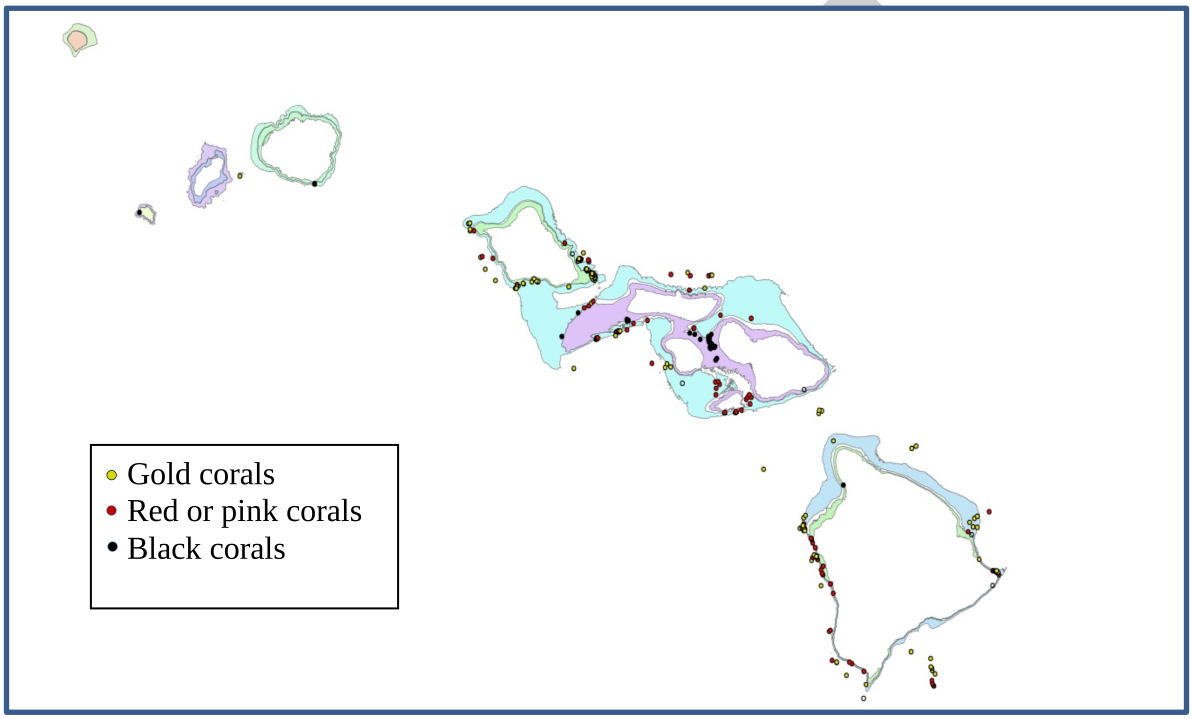

Figure 1. Observations of precious corals in the main Hawaiian Islands

Precious corals are found principally in three orders of the class Anthozoa: Gorgonacea, Antipatharia, and Zoanthiae (Grigg, 1984). In the western Pacific region, pink coral (*Pleurocorallium secundum*), red coral (*Hemicorallium laauense*), gold coral (*Kulamanamana haumeaae*), black coral (*Antipathes* sp.) and bamboo coral (*Lepidisis olapa*) are the primary species/genera of commercial importance. Of these, the most valuable precious corals are species of the genera *Pleurorallium* and *Hemicorallium*, the pink and red corals (Grigg, 1984). Pink coral (*P. secundum*) and Midway deep-sea coral (*Corallium* sp. nov,) are two of the principal species of commercial importance in the Hawaiian and Emperor Seamount chain (Grigg, 1984). *P. secundum*, is found in the Hawaiian archipelago from Milwaukee Banks in the Emperor Seamounts (36^{o}N) to the Island of Hawaii (18^{o}N); *Corallium* sp. nov. is found between 28^{o}–36^{o}N, from Midway to the Emperor Seamounts (Grigg, 1984). In addition to the pink corals, the bamboo corals, *Lepidistis olapa* and *Acanella* sp., are commercially important precious corals in the western Pacific region (Grigg, 1984). Pink coral and bamboo coral are found in the order

Gorgonacea in the subclass Octocorallia of the class Anthozoa, in the Phylum Coelenterata (Grigg, 1984).

The final two major groups of commercially important precious corals, gold coral and black coral, are found in separate orders, Zoanthidea and Antipatharia, in the subclass Hexacorallia, in the class Anthozoa and the phylum Coelenterata. The gold coral, *Kulamanamana haumeaae* (prev. *Gerardia* sp.) (Sinneger, *et.al.*, 2013), is endemic to the Hawaiian and Emperor Seamount chain (Grigg 1984). It inhabits depths ranging from 300–400 m (Grigg 1974, 1984). In Hawaii, gold coral, *Kulamanamana haumeaae,* grows mostly on bamboo hosts (e.g. *Acanella, Keratoisis*) as a parasitic overgrowth (Brown, 1976; Grigg, 1984; Parrish, 2015). Gold coral is, therefore, only found growing in areas that were previously inhabited by colonies of *Acanella* (Grigg, 1993) and possibly other bamboo corals (Parrish, 2015). Despite its ecological significance and long history of exploitation, the Hawaiian gold coral has never been subject to taxonomic studies or a formal species description. As a result of this, the nomenclature concerning the Hawaiian gold coral has been relatively confused. Symptomatic of the order, a suite of other zoanthids, besides the Hawaiian gold coral, have been observed and collected in Hawaii, but far less is known of their biology and ecology and they have not been described taxonomically.(Sinnegar *et al.,* 2013).

Grigg (1984) classified black corals in the order *Antipatharia*, and identified fourteen genera of black corals reported from the Hawaii-Pacific region with species found in both shallow and deep habitats Grigg, 1965). Wagner (2015) noted that there are over 235 known species of black coral that occur in the oceans of the world, and of this total, only about 10 species are of commercial importance (Grigg, 1984). Wagner (2011) confirmed 8 species of black corals in Hawaii, including (1) *Antipathes griggi* Opresko, 2009, (2) *Antipathes grandis* Verrill, 1928, (3) *Stichopathes echinulata* Brook, 1889, (4) an undescribed *Stichopathes* sp., (5) *Cirrhipathes* cf. *anguina* Dana, 1846, (6) *Aphanipathes verticillata* Brook, 1889, (7) *Acanthopathes undulata* (Van Pesch, 1914), and (8) *Myriopathes* cf. *ulex* Ellis & Solander, 1786. A new name for the Hawaiian species of antipatharian coral previously identified as *Antipathes dichotoma* (Grigg and Opresko, 1977) is described as *Antipathes griggi* (Opresko, 2009).

Many species of gorgonian corals are known to occur within the habitat of pink, gold and bamboo corals in the Hawaiian Islands. At least 37 species of precious corals in the order Gorgonacea have been identified from the Makapuu bed (Grigg and Bayer, 1976). In addition, 18 species of black coral (order Antipatharia) have been reported to occur in Hawaiian waters (Grigg and Opresko, 1977; Oishi, 1990; Wagner, 2011.), but only 3 of these species have been subject to commercial harvest (Oishi, 1990; Wagner *et al.,* 2015).

1.3 Biology and Life History

The management and conservation of deep-sea coral communities is challenged by their commercial harvest for the jewelry trade and damage caused by deep-water fishing practices. In light of their unusual longevity, a better understanding of deep-sea coral ecology and their interrelationships with associated benthic communities is needed to inform coherent international conservation strategies for these important deep-sea habitat-forming species (Bruckner, 2013).

Most of the interior of the global ocean remains unobserved. This leaves questions of trophic connectivity, longevity, and population dynamics of many deep-sea communities unanswered. Deep-sea megafauna provide a complex, rich, and varied habitat that promotes high biodiversity and provides congregation points for juvenile and adult fish (Freiwald *et al.,* 2004; Husebo *et al.,* 2002; Smith *et al.,* 2008).

Precious corals may be divided primarily into two groups of species based on their depth ranges: the deepwater species (200-600m) and the shallow water species (20-120m). Other precious corals can be found in depths down to 2000 m, but these species are not exploited in the U.S. for commercial purposes. Deep-sea corals are found on hard substrates on seamounts and continental margins worldwide at depths of 300 to 3,000 m.

Deep Corals
The Pacific Islands deepwater precious coral species include pink coral, *Pleurocorallium secundum* (prev. *Corallium secundum*), red coral, *Hemicorallium laauense* (prev. *C. regale or C. laauense*), gold coral, *Kulamanamana haumeaae (*prev. *Gerardia sp*.) and bamboo coral, *Lepidistis olapa*. As previously discussed, the most valuable precious corals are gorgonian octocorals (Grigg, 1984). There are seven varieties of pink and red precious corals in the western Pacific region, six of which used to be recognized as distinct species of *Corallium* (Grigg, 1981), but have been reclassified (Parrish *et al.,* 2015). The two species of commercial importance in the EEZ around the Hawaiian Islands are the pink coral *Pleurocorallium secundum* (prev. *Corallium secundum*), and the red coral, *Hemicorallium laauense* (prev. *C. laauense*). The Gorgonian octocorals are by far the most abundant and diverse corals in the Hawaiian Archipelago. Two species, *Pleurocorallium secundum* and *Hemicorallium laauense* are known to occur at depths of 300-600 m on islands and seamounts throughout the Hawaiian Archipelago (Grigg 1974, 1993; Parrish *et al.,* 2015; Parrish and Baco, 2007). Parrish (2007) surveyed *Pleurocorallium secundum* and *Hemicorallium laauense* at 6 precious coral beds in the lower Hawaiian chain, from Brooks Bank to Keahole Point, Hawaii, in depths ranging from 350m to 500m. He found corals on summits, flanks, and shallow banks, with bottom substrate and relief at these sites ranging from a homogenous continuum of one type to a combination of many types at a single site. The survey results show that all three coral taxa colonize both carbonate and basalt/manganese substrates, and the corals favor areas where bottom relief enhances or modifies flow characteristics that may improve the colony's feeding success.

These corals can grow to more than 30 cm in height, and are often found in large beds with other octocorals, zoanthids, and sometimes scleractinians (Parrish *et al.,* 2015; Parrish and Baco, 2007). These species are relatively long lived, with some of the oldest colonies observed within Makapuu Bed about 0.7 m in height and at least 80 years old (Grigg, 1988b, Roark, 2006). Populations of *P. secundum* appear to be recruitment limited, although in favorable environments (e.g., Makapuu Bed) populations are relatively stable, suggesting that recruitment and mortality are in a steady state (Grigg, 1993). A study by Roark *et al.* (2006) showed that the radial growth rate for specimens of *P. secundum* in the Hawaiian Islands is ~170 µm yr^{-1} and average age is 67 to 71 years, o;der than previously calculated. Individual colonies have been measured as tall as 28 cm. Bruckner (2009) suggested that the minimum allowable size for genus Corallium for harvest should be increased, and supported a potential listing for Corallium within the Appendices of the Convention on International Trade in Endangered Species (CITES). The current size restriction in the 2010 Code of Federal Regulations for Pacific Islands Region is 10 in (25.4 cm).

In Cairn's reviews (2008; 2009; 2010), he summarized the research conducted on Hawaiian Octocorallia taxa, including three gold coral PCMUS genuses, *Narella*, *Calyptrophora* and *Callogorgia*. Octocorallia are distributed over all ocean basins, found in depths ranging from shallow (~ 50m) to deep (~ 4,600) in Alaska. All gold PCMUS in Hawaii were collected in deep water (> 270m), throughout the Hawaiian archipelago and adjacent seamounts. Although these octocorals are managed as PCMUS, the only commercially exploited gold coral is the zoantharian, *Kulamanamana haumeaae* (prev. *Gerardia* sp.). It is probably the most common and largest of the zoanthids in Hawaii, and is widely distributed throughout the Hawaiian Archipelago and into the Emperor Seamount Chain at depths of 350–600 meters (Parrish *et al.*, 2015; Parrish and Baco, 2007). While subject to commercial exploitation from the 1970's until 2001 with an interruption between 1979 and 1999 (Grigg, 2001), the gold coral is not currently exploited in Hawaii due to a moratorium on the fishery. The Hawaiian gold coral is one of the largest and numerically dominant benthic macro-invertebrates in its depth range on hard substrate habitats of the Hawaiian Archipelago, and plays an important ecological role in Hawaiian seamount benthic assemblage (Parrish, 2006; Parrish and Baco, 2007; Parrish, *et al.*, 2015). The Hawaiian gold coral has also been found to be one of the longest-lived species on earth. Earlier ageing attempts on the gold coral focused on ring counts (Grigg, 1974; Grigg, 2002) and led to a maximal estimated age of 70 years and a radial growth rate (increase in branch diameter) of 1 mm/year. Recent studies using radiometric data suggest colonies of Hawaiian gold coral are as old as 2740 year with a radial growth rate of only 15 to 45 µm/year (Roark *et al.*, 2006; Roark *et.al.*, 2009; Parrish and Roark, 2009).

Parrish (2015) has found the host of the parasitic *Kulamanamana haumeaae* to be primarily the bamboo corals (e.g. Acanella, Keratoisis). *K. haumeaae* secretes a protein skeleton that over millennia can grow and more than double the original mean size of the host colony. It is relatively common and even dominant at geologically older sample sites, but recruitment is probably infrequent (Parrish, 2015). Although it can be relatively common compared to some other deep corals, it grows very slowly. Parrish and Roark (2009) determined that the Hawaiian gold coral *Kulamanamana haumeaae* has a mean life span of 950 yrs with an overall radial growth of ~41 µm yr^{-1}, and a gross radiocarbon linear growth rate of 2.2 ± 0.2 mm yr^{-1}. This is a much slower growth rate and longer life span than given in previous studies. Grigg (2002) reported a 1 mm yr^{-1} radial growth rate, equivalent to a 6.6 cm yr^{-1} linear growth for a maximum life span of roughly 70 yrs. This means these corals are growing much slower than previously thought, and have much longer life spans if undisturbed. Newly applied radiocarbon age dates from the deep water proteinaceous corals *Gerardia* and *Leiopathes* show that radial growth rates are as low as 4 to 35 micometers per year and that individual colony longevities are on the order of thousands of years (Roark *et al.*, 2009, 2006). The longest-lived *Gerardia* sp. and *Leiopathes* specimens were estimated to be 2,742 years old and 4,265 years old, respectively. *Gerardia* sp. is a colonial zoanthid with a hard skeleton of hard proteinaceous matter that forms tree-like structures with heights of several meters and basal diameters up to 10s of a centimeter. Black corals of *Leiopathes sp*. also has a hard proteinaceous skeleton and grows to heights in excess of 2 m. In Hawai'ian waters, these corals are found at depths of 300 to 500 m on hard substrates, such as seamounts and ledges.

The two bamboo coral PCMUS in the Pacific Islands Region are classified under two genera, Acanella and Lepidisis. Not much work has been done specifically on these genera, but Parrish (2015) identified branched bamboo colonies such as Acanella as a preferred host for *Kulamanamana haumeaae*. Because of the long colony life span of >3000 yrs and the bony hard bodied calcareous internodes of bamboo corals (family Isididae), geochemists are interested in using them to analyze paleo-oceanographic events and long-term climate change (Hill *et al*. 2011), while biologists use them to size and age deep-sea coral populations. Recent studies show that the subfamily Keratoisidinae (family Isididae) consists of four genera (*Acanella*, *Isidella*, *Lepidisis*, and *Keratoisis*), with two genera (*Tenuisis* and *Australisis*) perhaps belonging elsewhere in the Isididae family (Etnoyer 2008; France 2007). Bamboo corals commonly colonize intermediate to deep water depths (400m to >3000m) of continental slopes and seamounts in the Pacific Ocean.

Shallow Corals

The second group of precious coral species is found in shallow water between 20 and 120 m (Grigg, 1993 and Drysdale, *unpublished data*, 2012; Wagner *et al.*, 2015). The shallow water fishery is comprised of three species of black coral, *Antipathes griggi*, *A. grandis* and *Myriopathes ulex,* which have historically been harvested in Hawaii (Oishi 1990), but over 90% of the coral harvested by the fishery consists of *A. griggi* (Oishi 1990; Parrish *et al.*, 2015; Wagner *et al.*, 2015). Other black coral species are found in the NWHI in a wider depth range (20m to 1,400m), but with lower colony density (Wagner *et al*., 2011). Surveys performed in depths of 40-110 meters in the Au‘au Channel in 1975 and 1998, suggested stability in both recruitment and growth of commercially valuable black coral populations, and thus indicated that the fishery had been sustainable over this time period (Grigg, 2001). Subsequent surveys performed in the channel in 2001 indicated a substantial decline in the abundance of black coral colonies, with likely causes including increases in harvesting pressure and overgrowth of black coral colonies by the invasive octocoral *Carijoa sp.* and the red alga, *Acanthophora spicifera*, especially on reproductively mature colonies at mesophotic depths (Grigg 2003; Grigg 2004; Kahng & Grigg 2005; Kahng, 2006). Together, these factors renewed scrutiny on the black coral fishery and raised questions about whether regulations need to be redefined in order to maintain a sustainable harvest (Grigg, 2004). In addition to these challenges, Wagner has suggested that taxonomic misidentification has led to the mistaken belief that there is a depth refuge that exists for certain harvested species (Wagner *et al.,* 2012; Wagner, 2011). All of these uncertainties and lack of basic life history information regarding black corals complicates effective management of the resource (Grigg, 2004).

In Hawaii, *A. griggi* accounts for around 90% of the commercial harvest of black coral (Oishi 1990). *A. grandis* accounts for 9% and *M. ulex* 1% of the total black corals harvested. In Hawaii, roughly 85% of all black coral harvested are taken from within state waters. Black corals are managed jointly by the State of Hawaii and the Council. Within state waters (0–3 nmi), black corals are managed by the State of Hawaii (Grigg, 1993).

A new name for the Hawaiian species of antipatharian coral previously identified as *Antipathes dichotoma* (Grigg and Opresko, 1977) is described as *Antipathes griggi* Opresko, n. sp. (Opresko, 2009). The shallow water black coral *A. dichotoma* (*A. griggi)* collected at 50m exhibited growth rates of 6.42 cm yr^{-1} over a 3.5 yrs study.

1.4 Growth and Reproduction

There is very limited published literature regarding coral spawning of the PCMUS in the Pacific Islands Region. However, studies by Gleason, *et al*. (2006) and Waller and Baco (2007) indicate that the gold coral *Kulamanamana haumaae* may have seasonal reproduction, and that two pink coral species have a periodic or quasi-continuous reproductive periodicity. Although limited studies about growth rates and life spans of adult PCMUS in the Pacific Islands Region are available, early life history data on larvae, polyps, and juvenile colonies of the PCMUS are unavailable. Many other questions related to genetic connectivity and spatial distribution across the Pacific also remain unanswered. Recent mesophotic coral reef ecosystem studies provide an outline of essential knowledge for the limited deep water coral ecosystem (Kahng, *et al*. 2010). Slow-growing deep-water coral ecosystems are sensitive to many disturbances, such as temperature change, invasive species and destructive fishing techniques.

While different species of precious corals inhabit distinct depth zones, their habitat requirements are strikingly similar. Grigg (1984) noted that these corals are non-reef building and inhabit depth zones below the euphotic zone. In an earlier study, Grigg (1974) determined that precious corals are found in deep water on solid substrate in areas that are swept relatively clean by moderate to strong bottom currents (>25 cm/sec). Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Grigg (1984) notes that, in Hawaii, large stands of *Corralium* are only found in areas where

Table 3: Depth zonation of precious corals in the Western Pacific. (Source: Grigg 1993, Baco-Taylor, 2007, HURL and Drysdale, 2012)

Species and Common Name	Depth Range (m)
Paracorallium secundum Angle skin coral	250–575
Hemicorallium laauense Red coral	250–575
Corallium sp nov. Midway deepsea coral	1,000–1,500
Kulamanamana haumeaae (prev. *Gerardia* sp.) Hawaiian gold coral	350–575
Lepidisis olapa, *Acanella* spp. bamboo coral	250–1800
Antipathes griggi (prev. *A. dichotoma*), black coral	20–120
Antipathes grandis, pine black coral	20–120
Cirrhipathes cf. *anguina* (prev. *Antipathes anguina*), wire black coral	20–120
Myriopathes ulex (prev. *Antipathes ulex*),	20–220

Species and Common Name	Depth Range (m)
fern black coral	

sediments almost never accumulate, and *P. secundum* appears in large numbers in areas of high flow over carbonate pavement (Parrish *et al.,* 2015; Parrish and Baco, 2007). *Hemicorallium laauense* grows in an intermediate relief of outcrops; and *Kulamanamana haumaae* is most commonly seen growing in high relief areas on pinnacles, walls, and cliffs. These habitat differences may reflect preferred flow regimes for the different corals (e.g., laminar flow for *P. secundum*, alternating flow for *Kulamanamana haumaae*) (Parrish *et al.*, 2015).

Surveys of all potential sites for precious corals in the MHI conducted using a manned submersible show that most shelf areas in the MHI near 400 m are periodically covered with a thin layer of silt and sand (Grigg, 1984). Precious corals are known to grow on a variety of bottom substrate types. Precious coral yields, however, tend to be higher in areas of shell sandstone, limestone and basaltic or metamorphic rock with a limestone veneer. Grigg (1988) concludes that the concurrence of oceanographic features (strong currents, hard substrate, low sediments) necessary to create suitable precious coral habitat are rare in the MHI. Depth clearly influences the distribution of different coral taxa and certainly there is patchiness associated with the presence of premium substrate and environmental conditions (flow, particulate load, etc.). The environmental suitability for colonization and growth is likely to differ among coral taxa.

The habitat sustaining precious corals is generally in pristine condition. There are no known areas that have sustained damage due to resource exploitation, notwithstanding the alleged heavy foreign fishing for corals in the Hancock Seamounts area. Although unlikely, if future development projects are planned in the proximity of precious coral beds, care should be taken to prevent damage to the beds. Projects of particular concern would be those that suspend sediments or modify water-movement patterns, such as deep-sea mining or energy-related operations.

There has been very little research conducted concerning the food habits of precious corals. Precious corals are filter feeders (Grigg, 1984; 1993). The sparse research available suggests that particulate organic matter and microzooplankton are important in the diets of pink and bamboo coral (Grigg, 1970). Many species of pink coral, gold coral (*Kulamanamana haumeaae (*prev. *Gerardia* sp.*)* and black coral (*Antipathes*) form fan shaped colonies (Grigg, 1984; 1993). This type of morphological adaption maximizes the total area of water that is filtered by the polyps (Grigg, 1984; 1993). Bamboo coral (*Lepidisis olapa*), unlike other species of precious corals, is unbranched (Grigg, 1984). Long coils that trail in the prevailing currents maximize the total amount of seawater that is filtered by the polyps (Grigg, 1984). While clearly, the presence of strong currents is a vital factor determining habitat suitability for precious coral colonies, their role to date is not fully understood.

Light is one of the most important determining factors of the upper depth limit of many species of precious corals (Grigg, 1984).The larvae of two species of black coral, *Antipathes grandis* and *A. griggi*, are negatively phototaxic**.**

Grigg (1984) states that temperature does not appear to be a significant factor in delimiting suitable habitat for precious corals. In the Pacific Ocean, species of *Corallium* are found in temperature ranges of 8^{o} to $20^{o}C$, he observes. Temperature may determine the lower depth limits of some species of precious coral, including two species of black corals in the MHI. In the MHI, the lower depth range of two species of black corals (*A.griggi* and *A. grandis*) coincides with the top of the thermocline (about 100 m). Although, *A. griggi* can be found to depths of 100 m, it is rare below the 75 m depth limit at which commercial harvest occurs in Hawai‘i. Thus, the supposed depth refuge from harvest does not really exist, and was probably based on taxonomic misidentification, thereby calling into question population models used for the management of the Hawaiian black coral fishery (Wagner *et al.*, 2012; Wagner, 2011).

In pink coral (*P. secundum*), the sexes are separate (Grigg, 1993). Based on the best available data, it is believed that *P. secundum* becomes sexually mature at a height of approximately 12 cm (13 years) (Grigg, 1976). Pink coral reproduce annually, with spawning occurring during the summer, during the months of June and July. Coral polyps produce eggs and sperm. Fertilization of the oocytes is completed externally in the water column (Grigg, 1976; 1993). The resulting larvae, called planulae, drift with the prevailing currents until finding a suitable site for settlement.

Pink, bamboo and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. Grigg (1993) notes that the lengths of the larval stage of all deepwater species of precious corals is unknown. Clean swept areas exposed to strong currents provide important sites for settlement of the larvae, Grigg adds. The larvae of several species of black coral (*Antipathes*) are negatively photoactic, he notes. They are most abundant in dimly lit areas, such as beneath overhangs in waters deeper than 30 m. In an earlier study, Grigg (1976) found that “within their depth ranges, both species are highly aggregated and are most frequently found under vertical dropoffs. Such features are commonly associated with terraces and undercut notches relict of ancient sea level still stands. Such features are common off Kauai and Maui in the MHI. Both species are particularly abundant off of Maui and Kauai, suggesting that their abundance is related to suitable habitat.” Off of Oahu, many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments (Grigg, 1976).

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. These species of fish include onaga (*Etelis coruscans*), kahala (*Seriola dumerallii*) and the shrimp (*Heterocarpus ensifer*). These species do not seem to depend on the coral for shelter or food.

Densities of pink, gold and bamboo coral have been estimated for an unexploited section of the Makapuu bed (Grigg, 1976). As noted in the FMP for precious corals, the average density of pink coral in the Makapuu bed is 0.022 colonies/m^2. This figure was extrapolated to the entire bed (3.6 million m^2), giving an estimated standing crop of 79,200 colonies. At the 95% confidence limit, the standing crop is 47,500 to 111,700 colonies. The standing crop of colonies was converted to biomass ($3N_iW_i$), resulting in an estimate of 43,500 kg of pink coral in the Makapuu bed. These estimates need to be revised with more rigorous statistical enumeration methodologies.

In addition to coral densities, Grigg (1976) determined the age-frequency distribution of pink coral colonies in Makapuu bed. He applied annual growth rates to the size frequency to calculate the age structure of pink coral at Makapuu Bed (Table 4). More recent work by Roark *et al.* (2006) suggests that annual growth ring dating may underestimate the ages of many species of deep water corals, and that most of the colonies that have been dated using the ring method are probably older and slower growing than first estimated.

Estimates of density were also made for bamboo (*Lepidisis olapa*) and gold coral (*Kulamanamana haumeaae (*prev. *Gerardia* sp.*)* for Makapuu bed. The distributions of both these species are patchy. As noted in the FMP, the area where they occur comprises only half of that occupied by pink coral (1.8 km^2). Estimates of the unexploited abundance of bamboo and gold coral were 18,000 and 5,400 colonies, respectively. Estimates of density for the unexploited bamboo coral and gold coral in the Makapuu bed are 0.01 colonies/m^2 and 0.003 colonies/m^2. Using a rough estimate for the mean weights of gold and bamboo coral colonies (2.2 kg and 0.6 kg), a standing crop of about 11,880 kg of gold coral and 10,800 kg for bamboo for Makapuu bed was obtained. These estimates need to be revised with more rigorous statistical enumeration methodologies.

Growth rates for several species of precious corals found in the western Pacific region have been calculated. Grigg (1976) determines that the height of pink coral (*P. secundum*) colonies increases about 0.9 cm/yr up to about 30 years of age. These growth rates are probably overestimated, and should be revisited using modern methodologies. As noted in the FMP for precious corals, the height of the largest colonies of *Pleurocorallium secundum* at Makapuu bed rarely exceed 60 cm. Colonies of gold coral are known to grow up to 250 cm tall while bamboo corals may reach 300 cm. The natural mortality rate of pink coral at Makapuu bed is believed to be 0.066, equivalent to an annual survival rate of about 93%.

Table 4: Age-Frequency Distribution of *Pleurocorallium secundum* (Source: Grigg, 1973)

Age Group (years)	Number of Colonies
0–10	44
10–20	73
0–30	22
30–40	12
40–50	7
50–60	0

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