5.H.1(5)rev1

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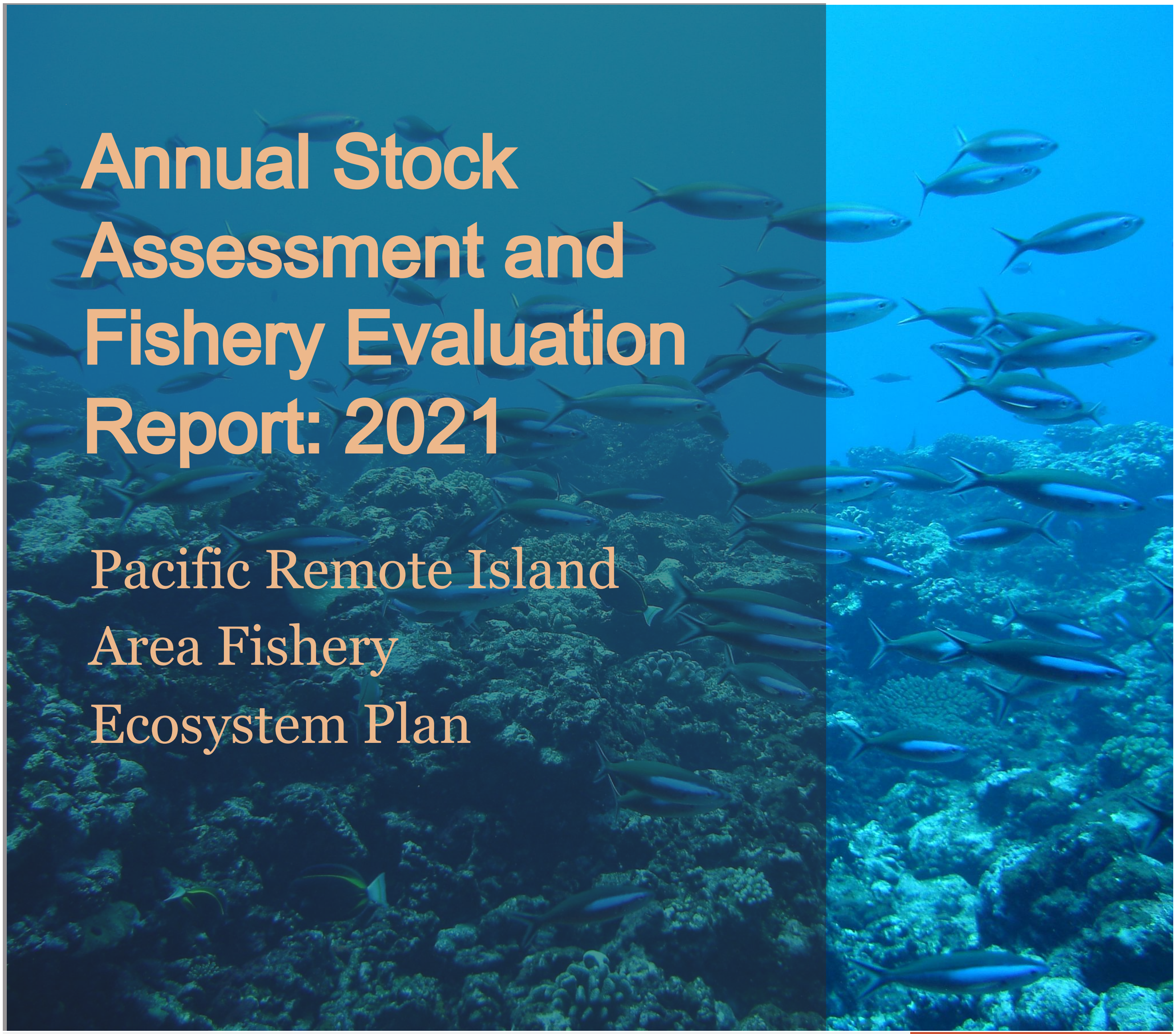

Annual Stock Assessment and Fishery Evaluation Report: 2021

Pacific Remote Island Area Fishery Ecosystem Plan

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

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

Edited By: Thomas Remington, Lynker & Marlowe Sabater, Matt Seeley, and Asuka Ishizaki, WPRFMC.

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

NMFS Pacific Islands Fisheries Science Center: Jenny Suter, Marc Nadon, Felipe Carvalho, Joseph O'Malley, Michael Parke, Kisei Tanaka Thomas Oliver, Melanie Abecassis, Frank Parrish, T. Todd Jones, Minling Pan, and Robert Ahrens.

NMFS Pacific Islands Regional Office: Brett Schumacher.

The Council also acknowledges the staff of the **NMFS PIFSC Fisheries Research and Monitoring Division data programs** for providing the technical support to generate the data summaries.

The Council would like to thank the following individual for their contributions to the report: Ian Bertram.

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EXECUTIVE SUMMARY

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

The 2021 Pacific Remote Island Area (PRIA) FEP annual SAFE report does not contain fully developed Fishery Performance or Data Integration chapters due to the absence of consistent fisheries data in the PRIA. Available data is acquired from the National Marine Fisheries Service (NMFS) Pacific Islands Regional Office (PIRO) Sustainable Fisheries Division (SFD) permits program. There were zero bottomfish permits issued in 2021, a decrease from four issued in 2018 and 2019. Similarly, there were no lobster or deepwater shrimp permits issued in 2021, and there is no record of these permits being issued since 2009 for lobster and 2010 for shrimp. There has been no logbook data reported since the establishment of federal permit and reporting requirements in 2006 for bottomfish and lobster and 2009 for shrimp. This is due to none of the issued permit holders reporting catch to PIRO SFD.

An Ecosystem Considerations chapter was added to the annual SAFE report following the Council's review of its FEPs and revised management objectives. Coral reef ecosystem parameter, protected species, socioeconomic, oceanic and climate indicator, essential fish habitat, and marine planning information are all included in this chapter.

Fishery independent ecosystem data were acquired through visual surveys conducted by the NMFS Pacific Islands Fisheries Science Center (PIFSC) Reef Assessment and Monitoring Program (RAMP) under the Ecosystem Sciences Division (ESD) in the PRIA, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), the Main Hawaiian Islands (MHI), and the Northwestern Hawaiian Islands (NWHI). This report describes mean fish biomass of functional, taxonomic, and trophic groups for coral reef areas as well as habitat condition using mean coral coverage per island averaged over the past decade for each of these locations. No new data were reported in 2020 or 2021 due to survey cancellations.

The highest amount of mean coral coverage from 2010 to 2019 in the PRIA was observed at Howland and Baker Islands at nearly 28% coverage, while the lowest observed was at Jarvis Island and Johnston Atoll at just over 10% coverage. Fish biomass varied between groups at each of the PRIA over the past decade. Wake Island had the lowest estimated fish biomass among the PRIA for all fishes, species of the family Lutjanidae, and for planktivores while having the highest biomass for species of the family Scaridae (though the standard error for the estimate was relatively high). Johnston Atoll had the lowest biomass for species of the family Serranidae and corallivores. Kingman Reef had the highest biomass for non-planktivorous butterflyfish and species of the family Lutjanidae while having the lowest biomass among the PRIA for herbivores. Palmyra Atoll had the highest biomass for mobile invertebrate feeders. Howland Island had the highest fish biomass among the PRIA for species of the family Serranidae, corallivores, and planktivores, but the lowest biomass for species of the family Scardiae. Jarvis Island had the highest biomass for all fishes, mid-large target surgeonfish, and herbivores.

The protected species section of this report describes monitoring and summarizes protected species interactions in fisheries managed under the PRIA FEP. There are currently no major bottomfish, crustacean, or precious coral fisheries operating in the PRIA, and no historical observer data are available for fisheries under this FEP. No new fishing activity was reported in 2021, and there is no new information to indicate that impacts to protected species from PRIA fisheries have changed over in recent years. Regarding the status of Endangered Species Act listing processes, leatherback sea turtles and cauliflower coral are no longer monitored in this report, since these processes concluded in 2020, and shortfin mako sharks were added.

The socioeconomics section is meant to outline the pertinent economic, social, and community information available for assessing the successes and impacts of management measures or the achievements of the FEP within the PRIA. The section provides an overview of the socioeconomic context for the region, but socioeconomic information is limited because human habitation is scarce. The socioeconomics section of this report will be expanded in later years if activity increases and as resources allow. There were no new socioeconomic data reported for the PRIA in 2021.

The climate change section of this report includes indicators of current and changing climate and related oceanic conditions in the geographic areas for which the Council has jurisdiction. In developing this section, the Council relied on a number of recent reports conducted in the context of the U.S. National Climate Assessment including, most notably, the 2012 Pacific Islands Regional Climate Assessment and the ‘Ocean and Coasts’ chapter of the 2014 report on a Pilot Indicator System prepared by the National Climate Assessment and Development Advisory Committee. The primary goal for selecting the indicators used in this report 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 considering changing climate, provide historical context, and recognize patterns and trends.

The trend of atmospheric concentration of carbon dioxide (CO_2) is increasing exponentially with a time series maximum at 416 ppm in 2021. Since 1989, the oceanic pH at Station ALOHA in Hawaii has shown a significant linear decrease of -0.042 pH units, or roughly a 10.2% increase in acidity ([H+]) and was 8.07 in 2020. The Oceanic Niño Index, which is a measure of the El Niño – Southern Oscillation (ENSO) phase, indicated La Niña conditions for most of 2021, with two consecutive neutral seasons punctuating the year mid-year. The Pacific Decadal Oscillation (PDO) was negative in 2021. The Accumulated Cyclone Energy (ACE) Index (x 104 kt^2) was below average in Eastern and Central North Pacific and average in the Western North and South Pacific. Annual mean sea surface temperature (SST) data was average in the PRIA grid and above average in the Johnston Atoll and Wake Atoll grids. After a major heat stress events in 2015, 2016, and 2019 that were relevant to coral bleaching, only Wake Atoll experienced another minor heat stress event in 2021. The chlorophyll-*a* concentrations around the PRIA were relatively lower in 2021 for Johnston Atoll and Wake Atoll, while the anomaly was slightly positive in the PRIA. Precipitation was slightly below average in the PRIA grid in 2010, while Wake Atoll had higher precipitation early in the year and Johnston Atoll had higher precipitation later in the year. Sea level rise is approximately 2.16 mm/year on Wake Atoll, which is equivalent to a change of 0.71 feet in 100 years.

The essential fish habitat (EFH) section of the 2010 annual SAFE report for the PRIA FEP includes responses to previous Council recommendations regarding EFH, habitat use by management unit species (MUS) in the PRIA, trends in habitat conditions, and levels of EFH information available for MUS. Guidelines also require a report on the condition of the habitat; mapping progress and benthic cover are included as preliminary indicators pending development of habitat condition indicators for the PRIA not otherwise represented in other sections of this report. The mean percent cover of live coral, macroalgae, and crustose coralline algae from RAMP sites collected from towed-diver surveys in the PRIA are also presented for the available years between 2001 and 2016. Levels of available EFH information are summarized for bottomfish, crustacean, and precious coral MUS. There were no Council directives to the Plan Team in 2021 associated with EFH for the PRIA.

The marine planning section of the annual SAFE report for the PRIA FEP tracks activities with multi-year planning horizons and begins to monitor the cumulative impact of established facilities. The Pacific Islands Marine National Monument remains intact around the islands and atolls of the PRIA. No new ocean activities were identified for the PRIA in 2021.

The Data Integration chapter of this report is not fully developed. In late 2016, the Council hosted a data integration workshop with participants from NMFS PIRO and PIFSC to identify policy-relevant fishery ecosystem relationships. However, no major updates have been made for the PRIA Data Integration chapter for the 2021 annual SAFE report. Despite the presence of data for certain ecological parameters throughout the PRIA, there exists no fishery performance data in the absence of consistent fishery-dependent information streams. In 2021, relevant abstracts of primary publications from the past year related to data integration were added. The chapter will be expanded in the future if fishing activity and data availability increases in the PRIA.

Plan Team members agreed to carry out the following recommendations, though none are relevant to the PRIA annual SAFE report:

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

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

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

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

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

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

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

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

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

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

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

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

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

9. Deferred the development of recommendations until the Office of National Marine Sanctuaries provides explicit boundaries for the proposed sanctuary relative to the Papahānaumokuākea Marine National Monument. When the sanctuary boundaries are further defined, the Archipelagic Plan Team will revisit this topic at a future meeting.

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

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

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

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

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ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
ACE	Accumulated Cyclone Energy
BiOp	Biological Opinion
BMUS	Bottomfish Management Unit Species
BRFA	Bottomfish Restricted Fishing Area
CFR	Code of Federal Regulations
Chl-A	Chlorophyll-*a*
CMAP	CPC Merged Analysis of Precipitation
CMUS	Crustacean Management Unit Species
CRED	Coral Reef Ecosystem Division (PIFSC)
CREP	Coral Reef Ecosystem Program (PIFSC)
CNMI	Commonwealth of the Northern Mariana Islands
COOPS	Center for Operational Oceanographic Products and Services
Council	Western Pacific Regional Fishery Management Council
CPC	Climate Prediction Center (NOAA)
CPUE	Catch Per Unit Effort
CREMUS	Coral Reef Ecosystem Management Unit Species
DIC	Dissolved Inorganic Carbon
DHW	Degree Heating Weeks
DPS	Distinct Population Segment
ECS	Ecosystem Component Species
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ENSO	El Niño – Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
ESD	Ecosystem Sciences Division (PIFSC)
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FR	Federal Register
FSSI	Fish Stock Sustainability Index
GAC	Global Area Coverage
HAPC	Habitat Area of Particular Concern
HOT	Hawaii Ocean Time Series
LAA	Likely to Adversely Affect
LAC	Local Area Coverage
LOC	Letter of Concurrence
LOF	List of Fisheries
MBTA	Migratory Bird Treaty Act
MCP	Marine Conservation Plan
MERIS	Moderate Resolution Imaging Spectroradiometer
MHI	Main Hawaiian Islands
MLCD	Marine Life Conservation District

Acronym	Meaning
MMA	Marine Managed Area
MMPA	Marine Mammal Protection Act
MODIS	Moderate Resolution Imaging Spectroradiometer
MPA	Marine Protected Area
MPCC	Marine Planning and Climate Change
MPCCC	MPCC Committee (WPRFMC)
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MUS	Management Unit Species
N/A	Not Applicable
NCADAC	National Climate Assessment and Development Advisory Committee
NCDC	National Climate Data Center
NEPA	National Environmental and Policy Act
NLAA	Not Likely to Adversely Affect
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NS	National Standard
NWHI	Northwestern Hawaiian Islands
ONI	Oceanic Niño Index
PCMUS	Precious Coral Management Unit Species
PDO	Pacific Decadal Oscillation
PIAFA	Pacific Insular Area Fishery Agreement
PIFSC	Pacific Islands Fisheries Science Center
PIRO	NOAA NMFS Pacific Islands Regional Office
PMUS	Pelagic Management Unit Species
ppm	Parts Per Million
PRI	Pacific Remote Islands
PRIA	Pacific Remote Island Areas
PRIMNM	Pacific Remote Islands Marine National Monument
RAMP	Reef Assessment and Monitoring Program (PIFSC)
RPB	Regional Planning Body
SAFE	Stock Assessment and Fishery Evaluation
SeaWiFS	Sea-Wide Field-of-View Sensor
Secretary	Secretary of Commerce
SFD	Sustainable Fisheries Division (PIRO)
SST	Sea Surface Temperature
TA	Total Alkalinity
TBA	To Be Announced
TBD	To Be Determined
USFWS	United States Fish and Wildlife Service
VIIRS	Visible and Infrared Imager/Radiometer Suite
WPRFMC	Western Pacific Regional Fishery Management Council

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1 FISHERY PERFORMANCE

Fisheries in the Pacific Remote Island Areas (PRIA), including Palmyra Atoll, Kingman Reef, Jarvis Island, Baker Island, Howland Island, Johnston Atoll, and Wake Island, are limited. Fishery performance data for the PRIA are presented where available.

1.1 FEDERAL LOGBOOK DATA

1.1.1 Number of Federal Permit Holders

The Code of Federal Regulations (CFR), Title 50 Part 665 requires the following federal permits for fishing in the exclusive economic zone (EEZ) of the PRIA.

1.1.1.1 Special Coral Reef Ecosystem Permit

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

1.1.1.2 Western Pacific Precious Corals Permit

Regulations require a Western Pacific Precious Corals permit for anyone harvesting or landing black, bamboo, pink, red, or gold corals in the EEZs of the U.S. Western Pacific.

1.1.1.3 Western Pacific Crustaceans Permit (Lobster or Deepwater Shrimp)

Regulations require a Western Pacific Crustaceans permit for any owner of a U.S. fishing vessel used to fish for lobster (now ECS) or deepwater shrimp in the EEZs around of the U.S. Western Pacific.

1.1.1.4 PRIA Bottomfish Permit

Regulations require obtaining a PRIA Bottomfish permit for anyone using bottomfish gear to fish for bottomfish MUS in the EEZ around the PRIA. Commercial fishing is prohibited within the boundaries of the Pacific Remote Islands Marine National Monument (PRIMNM).

There is no record of permits issued for the EEZ around the PRIA for the coral reef or precious coral fisheries since 2008, for the lobster fishery since 2009, and for the shrimp fishery since 2010. Table 1 provides the number of permits issued for PRIA fisheries from 2012 to 2021. Data were accessed from the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Regional Office (PIRO) Sustainable Fisheries Division (SFD) permits program.

Table 1. Number of federal permit holders in the FEP fisheries of the PRIA

PRIA Fisheries	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bottomfish	5	2	2	1	1	1	4	4	0	0
Lobster	0	0	0	0	0	0	0	0	0	0
Shrimp	0	0	0	0	0	0	0	0	0	0

Source: PIRO SFD unpublished data.

1.1.2 Summary of Catch and Effort for FEP Fisheries

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

1.1.2.1 Bottomfish

Table 2. Summary of available federal logbook data for bottomfish fisheries in the PRIA

Year	No. of Federal Permits Issued[1]	Federal Permits Reporting Catch	No. of Trips in PRIA EEZ	Total Reported Logbook Catch (lbs.)		Total Reported Logbook Release/Discard (lbs.)	
				Bottomfish MUS	*Coral Reef MUS*	*Bottomfish MUS*	*Coral Reef MUS*
2006	1	0					
2007	6	0					
2008	5	0					
2009	5	0					
2010	5	0					
2011	6	0					
2012	5	0					
2013	2	0					
2014	2	0					
2015	1	0					
2016	1	0					
2017	1	0					
2018	4	0					
2019	4	0					
2020	0						
2021	0						

[1] Source: PIRO SFD unpublished data.

Note: Federal permit and reporting requirements for PRIA bottomfish fisheries became effective on December 4, 2006 (71 FR 69496, December 1, 2006).

1.1.2.2 Spiny and Slipper Lobster

Table 3. Summary of available federal logbook data for lobster fisheries in the PRIA

Year	Federal Permits Issued[1]	Federal Permits Reporting Catch	No. of Trips in PRIA EEZ	Total Reported Logbook Catch (lbs.)		Total Reported Logbook Release/Discard (lbs.)	
				Spiny lobster MUS	*Slipper lobster MUS*	*Spiny lobster MUS*	*Slipper lobster MUS*
2006	0						
2007	3	0					
2008	5	0					
2009	4	0					
2010	0						
2011	0						
2012	0						
2013	0						
2014	0						
2015	0						
2016	0						
2017	0						
2018	0						
2019	0						
2020	0						
2021	0						

[1] Source: PIRO SFD unpublished data.

Note: Federal permit and reporting requirements for PRIA lobster fisheries became effective on December 4, 2006 (71 FR 69496, December 1, 2006).

1.1.2.3 Deepwater Shrimp

Table 4. Summary of available federal logbook data for deepwater shrimp fisheries in the PRIA

Year	Federal Permits Issued[1]	Federal Permits Reporting Catch	No. of Trips in PRIA EEZ	Total Reported Logbook Catch (lbs.)	Total Reported Logbook Release/Discard (lbs.)
2009	0				
2010	1	0			
2011	0				
2012	0				
2013	0				
2014	0				
2015	0				
2016	0				
2017	0				

Year	Federal Permits Issued[1]	Federal Permits Reporting Catch	No. of Trips in PRIA EEZ	Total Reported Logbook Catch (lbs.)	Total Reported Logbook Release/Discard (lbs.)
2018	0				
2019	0				
2020	0				
2021	0				

[1] Source: PIRO SFD unpublished data.
Note: Federal permit and reporting requirements for deepwater shrimp fisheries became effective on June 29, 2009 (74 FR 25650, May 29, 2009).

1.2 ADMINISTRATIVE AND REGULATORY ACTIONS

There were no management actions implemented for insular fisheries in the PRIA during calendar year 2021.

2 ECOSYSTEM CONSIDERATIONS

2.1 CORAL REEF FISH ECOSYSTEM PARAMETERS

2.1.1 Regional Reef Fish Biomass and Habitat Condition

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

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

Data Category: Fishery-independent

Timeframe: Triennial

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

Spatial Scale: Regional

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

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

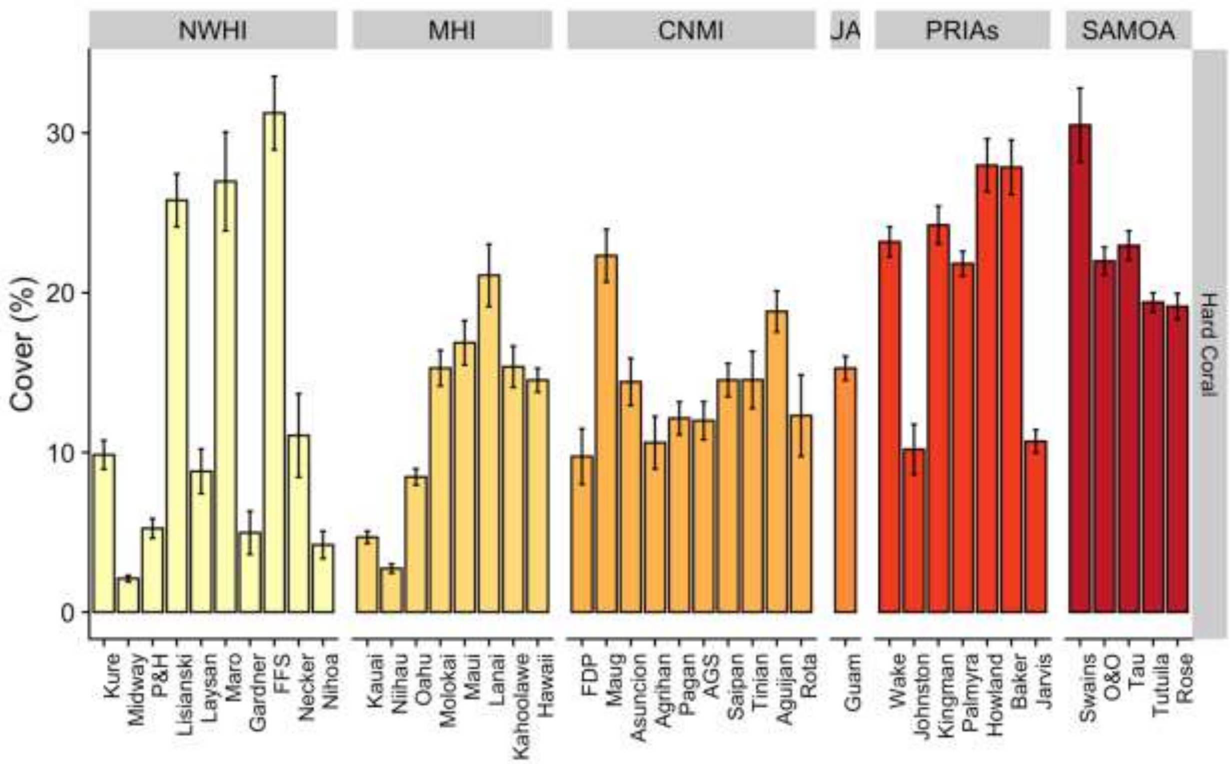

Figure 1. Mean coral cover (%) per U.S. Pacific Island averaged over the years 2010–2020 by latitude

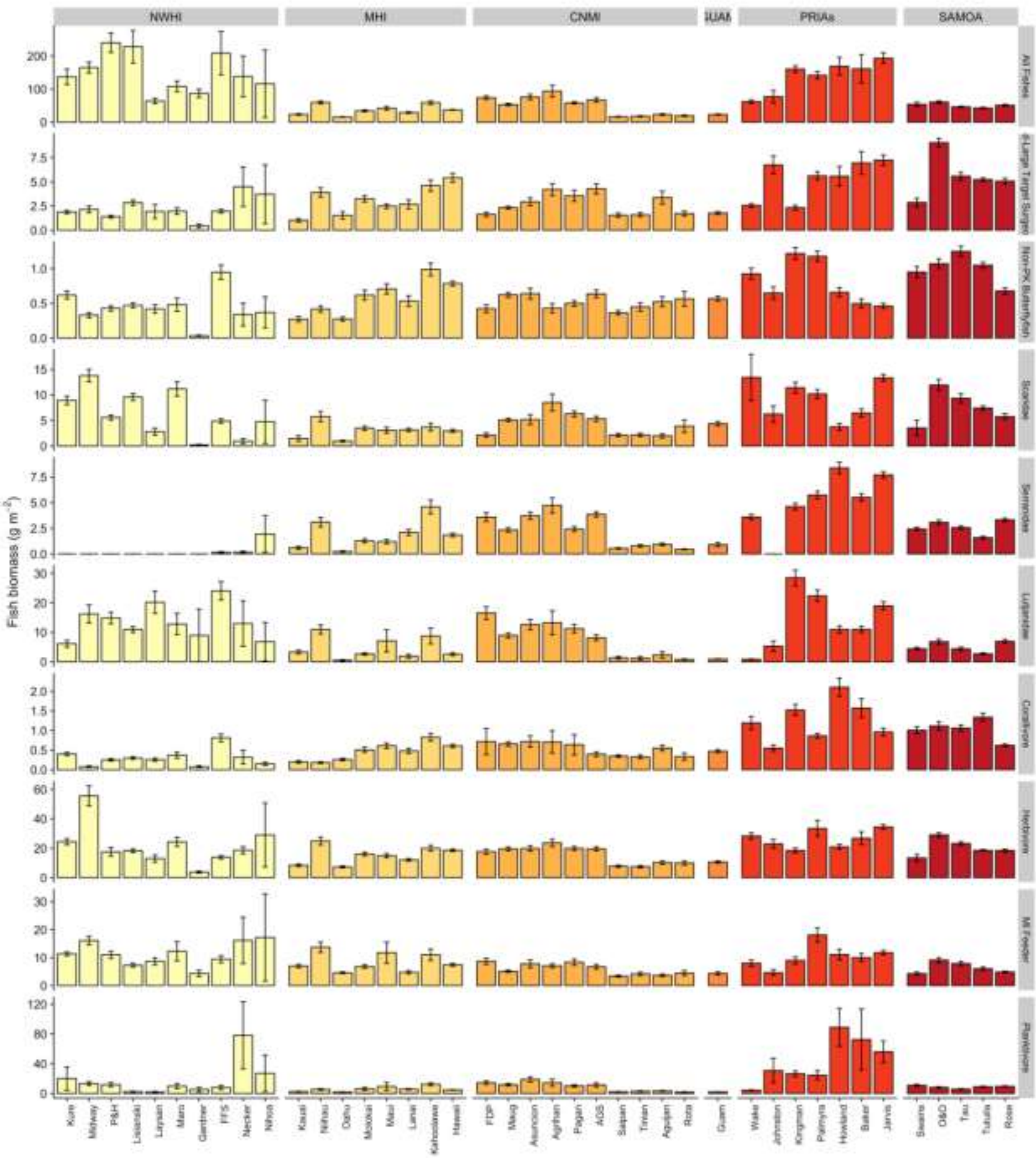

Figure 2. Mean fish biomass (g/m^2 ± standard error) of functional, taxonomic, and trophic groups by U.S. Pacific reef area from the years 2010–2020 by latitude. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group – as high biomass of that species at Wake Island overwhelms corallivore biomass at all other locations. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates

2.1.2 Archipelagic Reef Fish Biomass and Habitat Condition

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

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

Data Category: Fishery-independent

Timeframe: Triennial

Jurisdiction: PRIA

Spatial Scale: Island

Data Source: Data used to generate biomass and cover estimates comes from visual surveys conducted by NOAA PIFSC ESD and partners, as part of the Pacific RAMP. Survey methods and sampling design, and methods to generate reef fish biomass are described in Section 2.1.1.

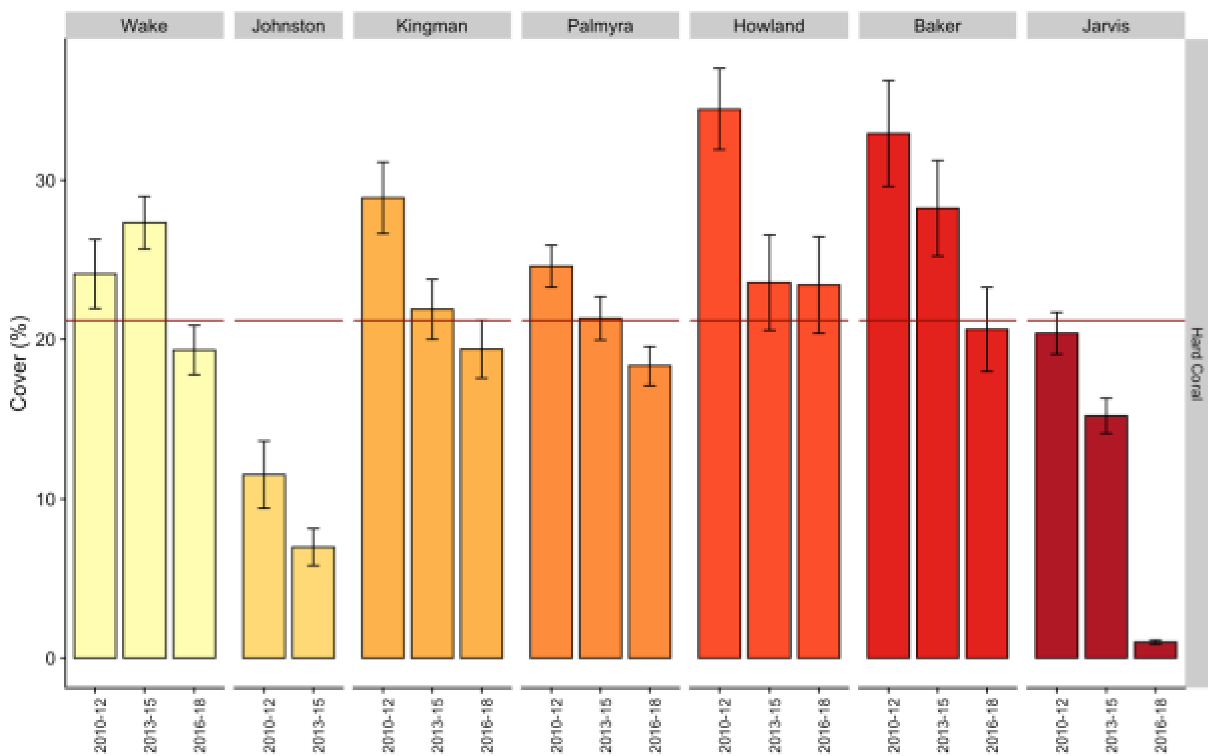

Figure 3. Mean coral cover (%) per island averaged over the years 2010–2020 by latitude with PRIA mean estimates plotted for reference (red line)

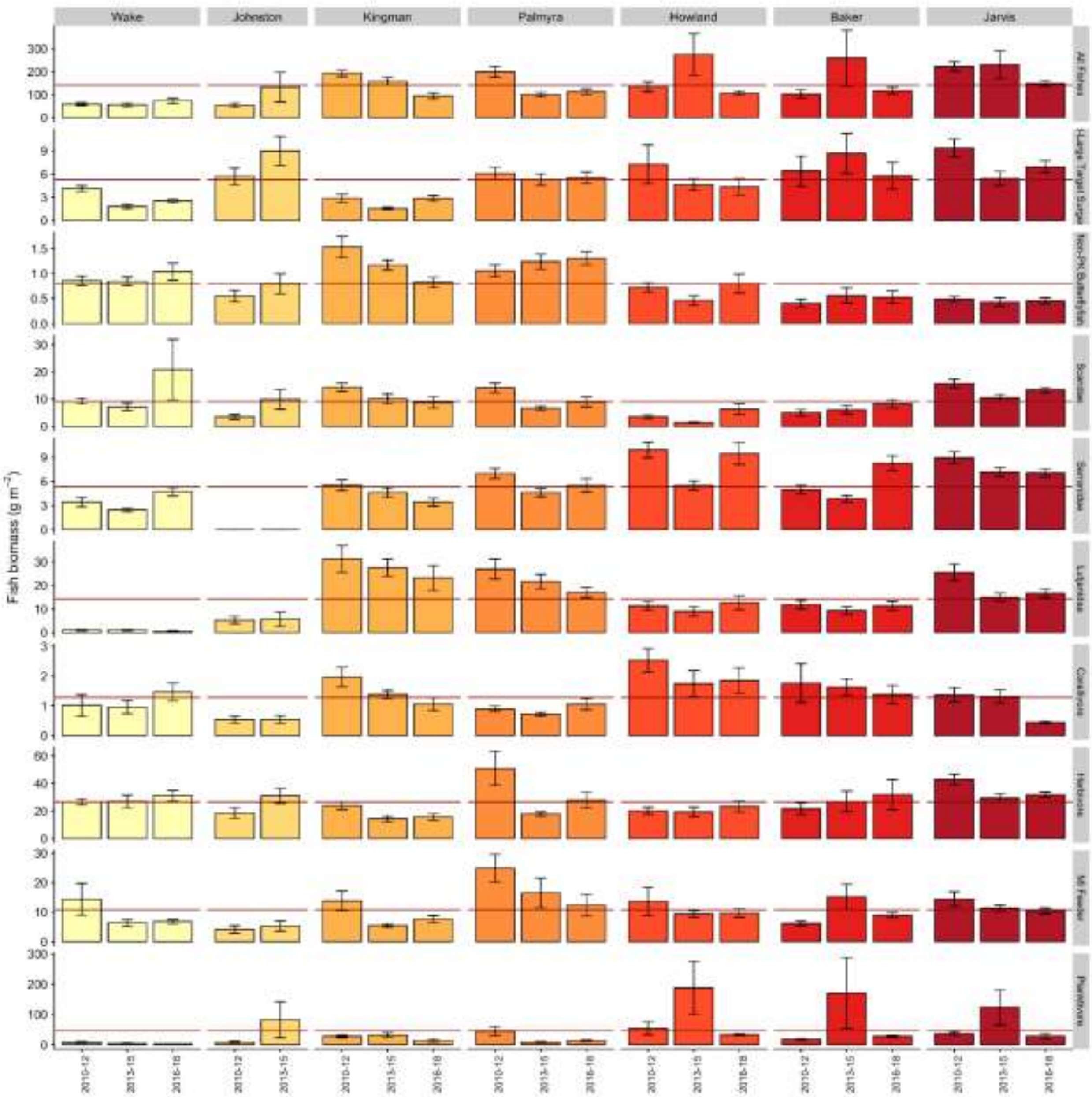

Figure 4. Mean fish biomass (g/m^2 ± standard error) of PRIA functional, taxonomic, and trophic groups from the years 2010–2020 by island. The group Serranidae excludes planktivorous members of that family (i.e., anthias, which can by hyper-abundant in some regions). Similarly, the bumphead parrotfish, *Bolbometopon muricatum*, has been excluded from the corallivore group. The group 'MI Feeder' consists of fishes that primarily feed on mobile invertebrates; with PRIA mean estimates plotted for reference (red line)

2.2 PROTECTED SPECIES

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

2.2.1 Monitoring Protected Species Interactions in the PRIA FEP Fisheries

This report monitors the status of 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. Logbook programs are not expected to provide reliable data about protected species interactions due to the lack of active fisheries in these areas.

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 prohibitions benefit 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 (USFWS; for species under their jurisdiction) to ensure ongoing fisheries operations managed under the PRIA FEP are not jeopardizing the continued existence of any ESA-listed species or adversely modifying critical habitat. The results of these consultations, conducted under section 7 of the ESA, are briefly described below and summarized in Table 5.

NMFS concluded on January 16, 2015 that all fisheries managed under the PRIA FEP have no effects on ESA-listed reef-building corals. NMFS concluded in an informal consultation dated February 20, 2015 that all fisheries managed under the PRIA FEP are not likely to adversely affect the Indo-West Pacific distinct population segment (DPS) of scalloped hammerhead shark.

Table 5. Summary of ESA consultations for PRIA FEP Fisheries

Fishery	Consultation Date	Consultation Type[a]	Outcome[b]	Species
Bottomfish	3/8/2002	BiOp	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, sei whale, sperm whale
Coral reef ecosystem	3/7/2002	LOC	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, sei whale, sperm whale
	5/22/2002	LOC (USFWS)	NLAA	Green, hawksbill, leatherback, loggerhead and olive ridley turtles, Newell's shearwater, short-tailed albatross, Laysan duck, Laysan finch, Nihoa finch, Nihoa millerbird, Micronesian megapode, 6 terrestrial plants
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
Crustacean	9/28/2007	LOC	NLAA	Loggerhead sea turtle, leatherback sea turtle, olive ridley sea turtle, green sea turtle, hawksbill sea turtle, humpback whale, blue whale, fin whale, sei whale, sperm whale
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
Precious coral	10/4/1978	BiOp	Does not constitute threat	Sperm whale, leatherback sea turtle
	12/20/2000	LOC	NLAA	Humpback whale, green sea turtle, hawksbill sea turtle
	9/18/2018	No effect memo	No effect	Oceanic whitetip shark, giant manta ray
All fisheries	1/16/2015	No effect memo	No effect	Reef-building corals
	2/20/2015	LOC	NLAA	Scalloped hammerhead shark (Indo-west Pacific DPS)

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

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).

Crustacean Fishery

An informal consultation completed by NMFS on September 28, 2007 concluded that PRIA 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).

On September 18, 2018, NMFS concluded that PRIA crustacean fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

Coral Reef Fishery

An informal consultation completed by NMFS on March 7, 2002 concluded that fishing activities conducted under the Coral Reef Ecosystems Fishery Management Plan (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).

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

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

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.

On September 18, 2018, NMFS concluded that PRIA precious coral reef fisheries will have no effect on the oceanic whitetip shark and giant manta ray.

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 due to the lack of active commercial fisheries.

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 Emerging Issues

Table 6 summarizes current candidate ESA species, recent listing status, and post-listing activity (critical habitat designation and recovery plan development). Impacts from FEP-managed fisheries on any new listings and critical habitat designations will be considered in future versions of this report.

Table 6. Status of candidate ESA species, recent ESA listing processes, and post-listing activities

Species		Listing Process			Post-Listing Activity	
Common Name	**Scientific Name**	**90-Day Finding**	**12-Month Finding / Proposed Rule**	**Final Rule**	**Critical Habitat**	**Recovery Plan**
Oceanic whitetip shark	*Carcharhinus longimanus*	Positive (81 FR 1376, 1/12/2016)	Positive, threatened (81 FR 96304, 12/29/2016)	Listed as threatened (83 FR 4153, 1/30/18)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (85 FR 12898, 3/5/2020)	In development; recovery planning workshops convened in 2019.
Giant manta ray	*Manta birostris*	Positive (81 FR 8874, 2/23/2016)	Positive, threatened (82 FRN 3694, 1/12/2017)	Listed as threatened (83 FR 2916, 1/22/18)	Designation not prudent; no areas within US jurisdiction that meet definition of critical habitat (84 FR 66652, 12/5/2019)	Recovery outline published 12/4/19 to serve as interim guidance until full recovery plan is developed; recovery planning workshop planned for 2021.
Corals	N/A	Positive for 82 species (75 FR 6616, 2/10/2010)	Positive for 66 species (77 FR 73219, 12/7/2012)	20 species listed as threatened (79 FR 53851, 9/10/2014)	Critical habitat proposed (85 FR 76262, 11/27/2021), comment period extended through 5/26/2021 (86 FR 16325)	In development, interim recovery outline in place; recovery workshops convened in May 2021.
Giant clams	*Hippopus hippopus*, *H. porcellanus*, *Tridacna costata*, *T. derasa*, *T. gigas*, *T. squamosa*,	Positive (82 FR 28946, 06/26/2017)	TBD (status review ongoing)	TBD	N/A	N/A

Species		**Listing Process**			**Post-Listing Activity**	
Common Name	**Scientific Name**	**90-Day Finding**	**12-Month Finding / Proposed Rule**	**Final Rule**	**Critical Habitat**	**Recovery Plan**
	and *T. tevoroa*					
Green sea turtle	*Chelonia mydas*	Positive (77 FR 45571, 8/1/2012)	Identification of 11 DPSs, endangered and threatened (80 FR 15271, 3/23/2015)	11 DPSs listed as endangered and threatened (81 FR 20057, 4/6/2016)	In development, proposal expected TBA	TBA
Shortfin Mako Shark	*Isurus oxyrinchus*	Positive (86 FR 19863, 04/15/2021	TBA (status review ongoing)	TBA	N/A	N/A

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

2.2.4 Identification of Research, Data, and Assessment Needs

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

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

2.3 SOCIOECONOMICS

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

In 1996, the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 8 (NS8) specified that conservation and management measures need to account for the importance of fishery resources in fishing communities, to support sustained participation in the fisheries, and to minimize adverse economic impacts, provided that these considerations do not compromise conservation. Unlike other regions of the United States, the settlement of the Western Pacific region was intimately tied to the ocean, which is reflected in local culture, customs, and traditions (Figure 5).

Figure 5. Settlement of the Pacific Islands, courtesy Wikimedia Commons (from https://commons.wikimedia.org/wiki/File:Polynesian_Migration.svg)

Polynesian voyagers relied on the ocean and marine resources on their long voyages in search of new islands, as well as in sustaining established island communities. Today, the population of the region also represents many Asian cultures from Pacific Rim countries, which have a similar reliance on marine resources. Thus, fishing and seafood are integral to local community ways of life. This is reflected in the amount of seafood eaten in the region relative to the rest of the United States, as well as in the language, customs, ceremonies, and community events. The amount of available seafood can also affect seasonality in prices of fish. Because fishing is such an integral part of the culture, it is difficult to discern commercial from non-commercial fishing where most trips involving multiple motivations and multiple uses of the fish caught. While the economic perspective is an important consideration, fishermen report other motivations, such as customary exchange, as being equally important. Due to changing economies and westernization, waning recruitment of younger fishermen is becoming a concern for the sustainability of fishing and fishing traditions in the region.

2.3.1 Response to Previous Council Recommendations

There were no Council recommendations related to socioeconomic considerations in the PRIA during 2021.

2.3.2 Background

Human habitation in the PRIAs is limited. The FEP for the PRIAs provides a description of the geography, history, and socioeconomic considerations of the archipelago (WPRFMC 2009). Grace-McCaskey (2014) provided a brief review of the importance of these areas from a cultural perspective. She noted that although the PRIAs were uninhabited when first visited by Westerners, Polynesians and Micronesians likely had been periodically visiting these islands for centuries. Many of the islands in the PRIAs were altered during World War 2, and many have subsequently become National Wildlife Refuges or part of the Pacific Remote Islands Marine National Monument (PRIMNM). Only Wake, Johnston, and Palmyra have seasonal- and year-round residents, primarily related to the U.S. military and refuge management. The surrounding reef ecosystems are considered to be some of the healthiest in the world due to their distance to areas of high human population densities, though some are experiencing residual impacts from military activity nearby. There are no designated fishing communities residing in the PRIAs. Most of the fishing effort has been concentrated around Johnston and Palmyra Atolls by members of the Hawaii fishing community.

2.3.3 Ongoing Research and Information Collection

There is currently no ongoing research specific to the PRIA.

2.3.4 Relevant PIFSC Economics and Human Dimensions Publications: 2021

There were no relevant PIFSC publications regarding the economics or human dimensions of the PRIA in 2021.

2.4 CLIMATE AND OCEANIC INDICATORS

2.4.1 Introduction

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

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

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

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

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

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

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

2.4.1.1 Response to Previous Council Recommendations

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

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 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 impact 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 6).

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

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

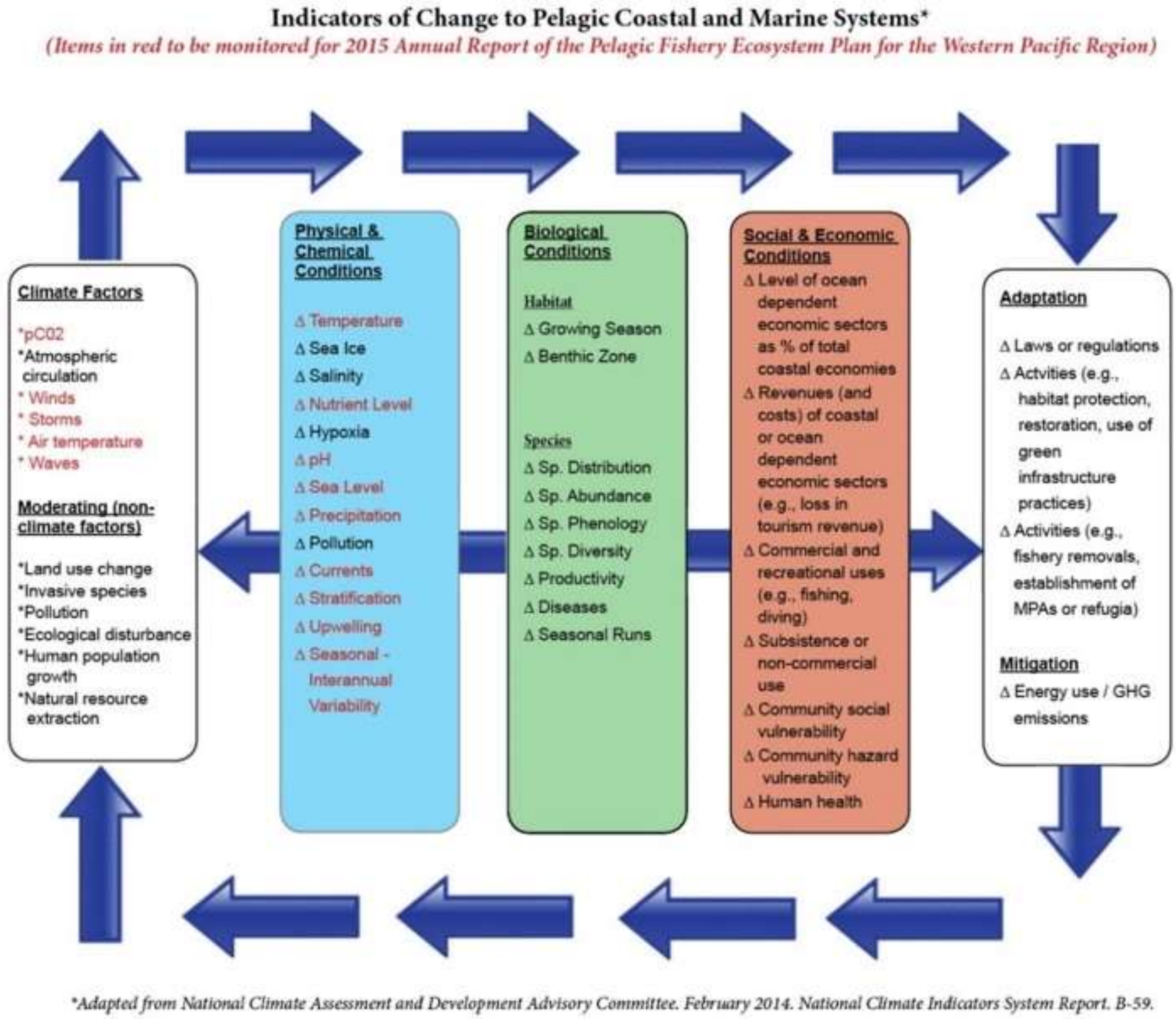

Figure 6. Indicators of change of pelagic coastal and marine systems; conceptual model

2.4.3 Selected Indicators

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

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

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

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

Figure 7 and Figure 8 provide a description of these indicators and illustrate how they are connected to each other in terms of natural climate variability and anthropogenic climate change.

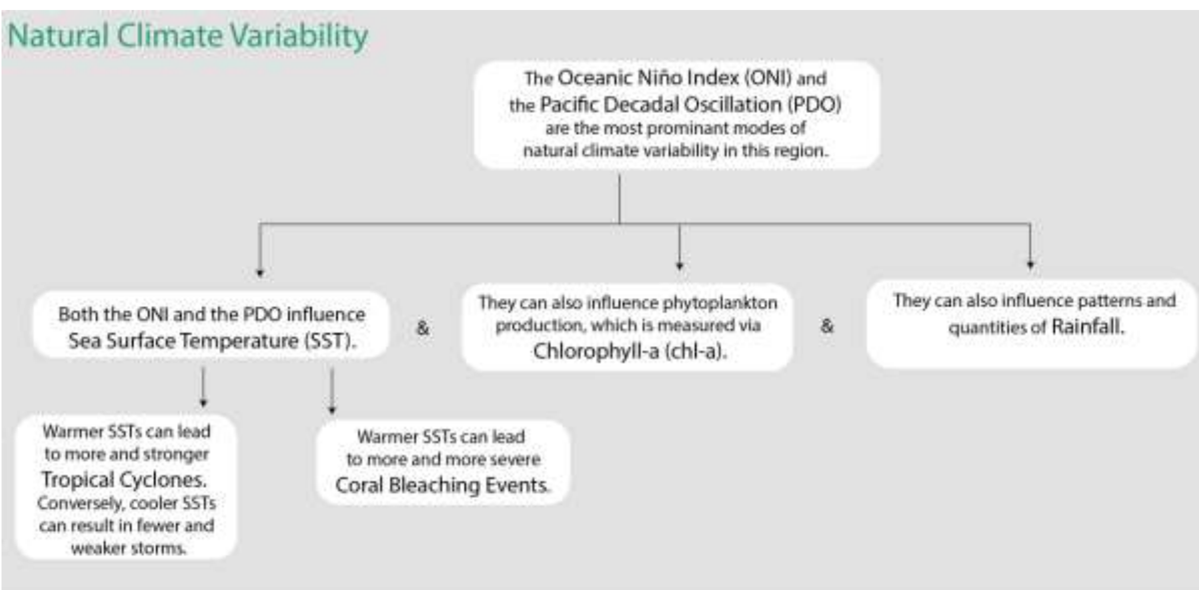

Figure 7. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of natural climate variability

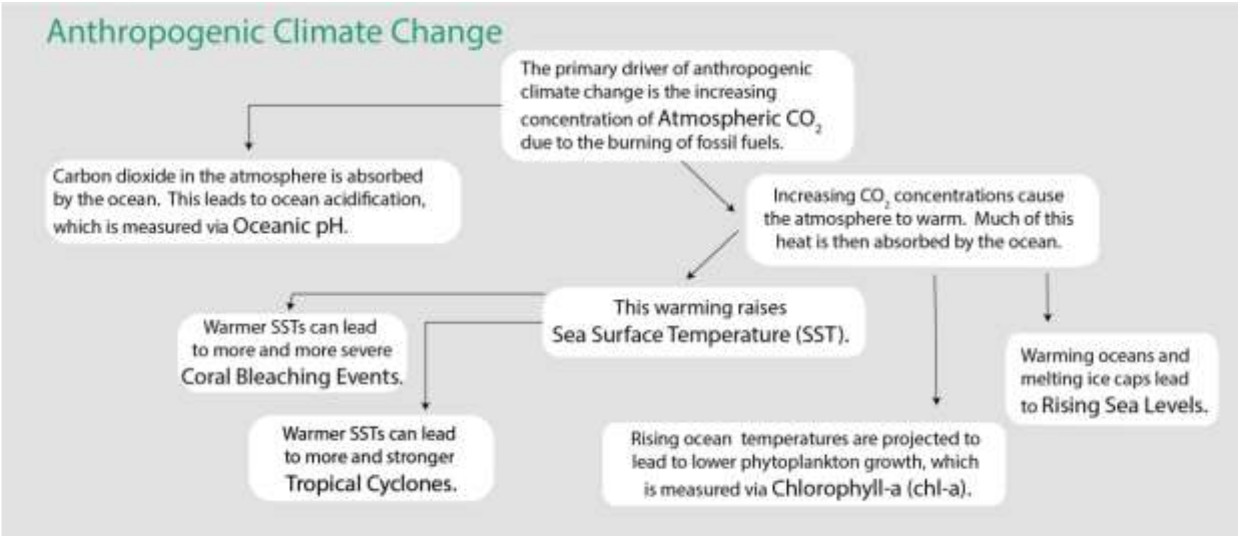

Figure 8. Schematic diagram illustrating how indicators are connected to one another and how they vary as a result of anthropogenic climate change

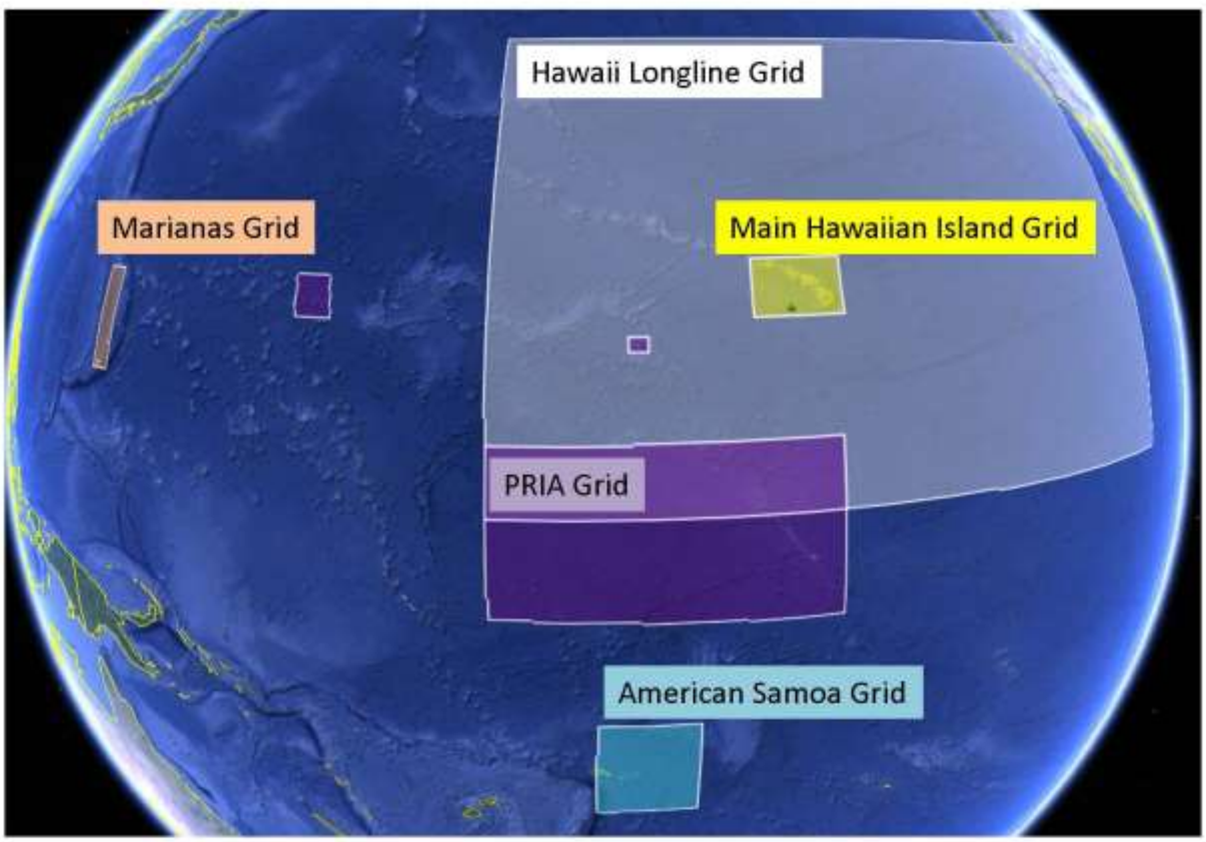

Figure 9. Regional spatial grids representing the scale of the climate change indicators being monitored

2.4.3.1 Atmospheric Concentration of Carbon Dioxide at Mauna Loa

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

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

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

Timeframe: Annual, monthly.

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

Measurement Platform: *In-situ* station.

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

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

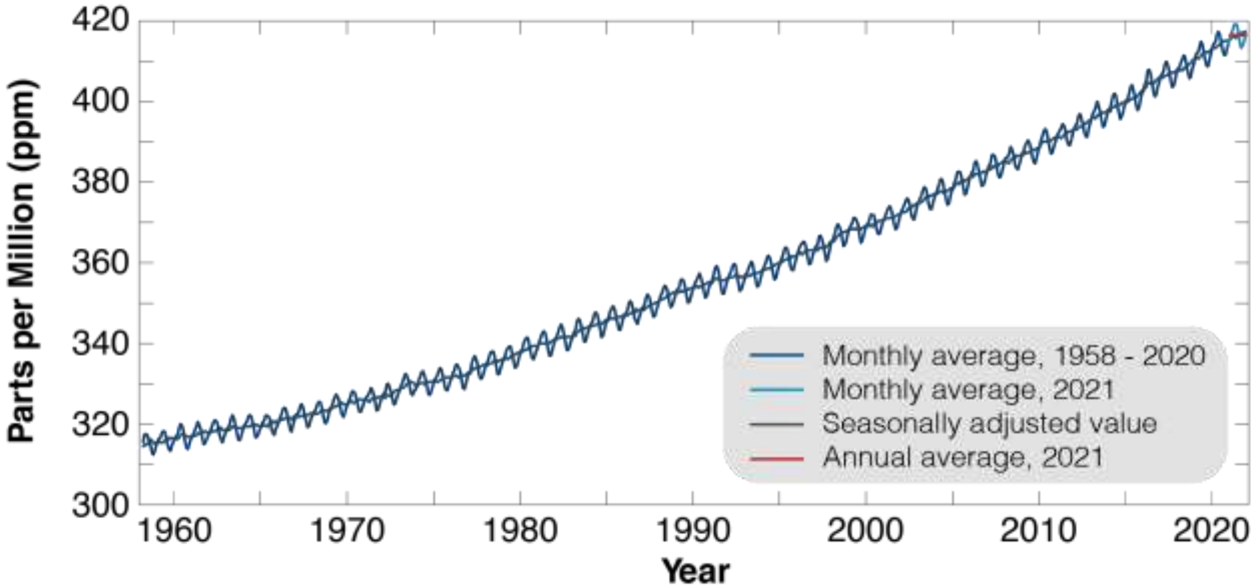

Figure 10. Monthly mean (black) and seasonally corrected (blue) atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii

2.4.3.2 Oceanic pH

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

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

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

Timeframe: Monthly.

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

Measurement Platform: *In-situ* station.

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

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

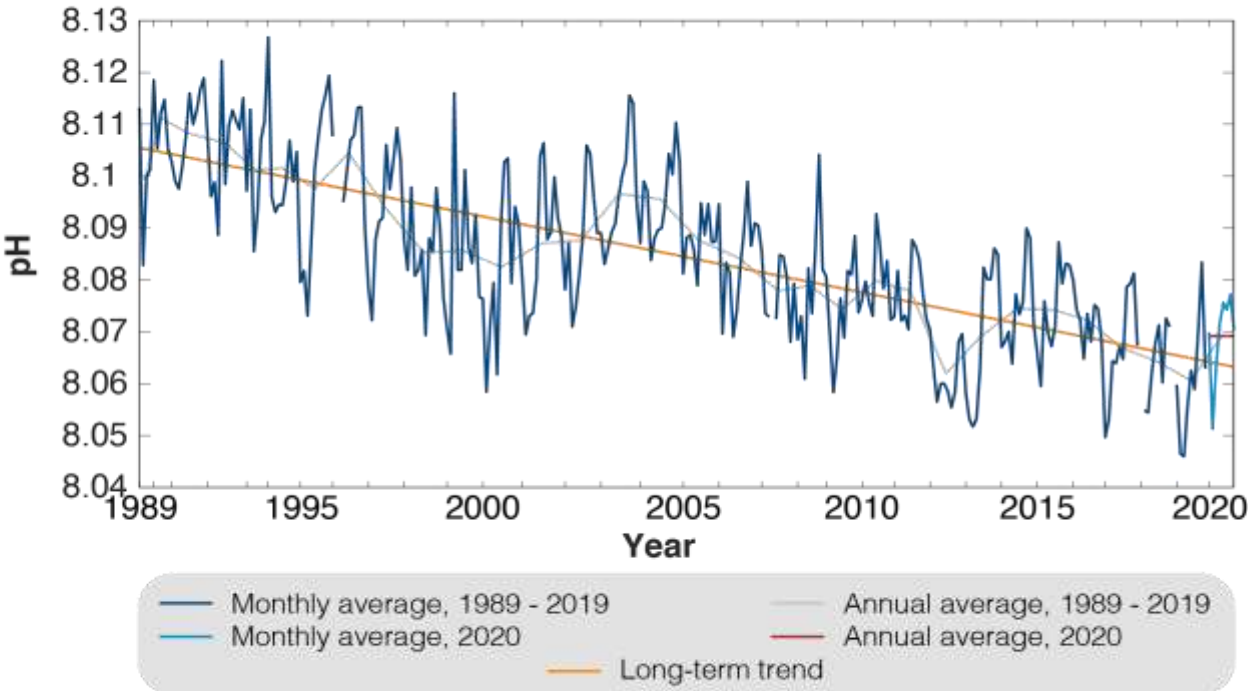

Figure 11. Time series and long-term trend of oceanic pH measured at Station ALOHA from 1989–2020

2.4.3.3 Oceanic Niño Index

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

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

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

Timeframe: Every three months.

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

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

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

Sourced from NOAA CPC (2022).

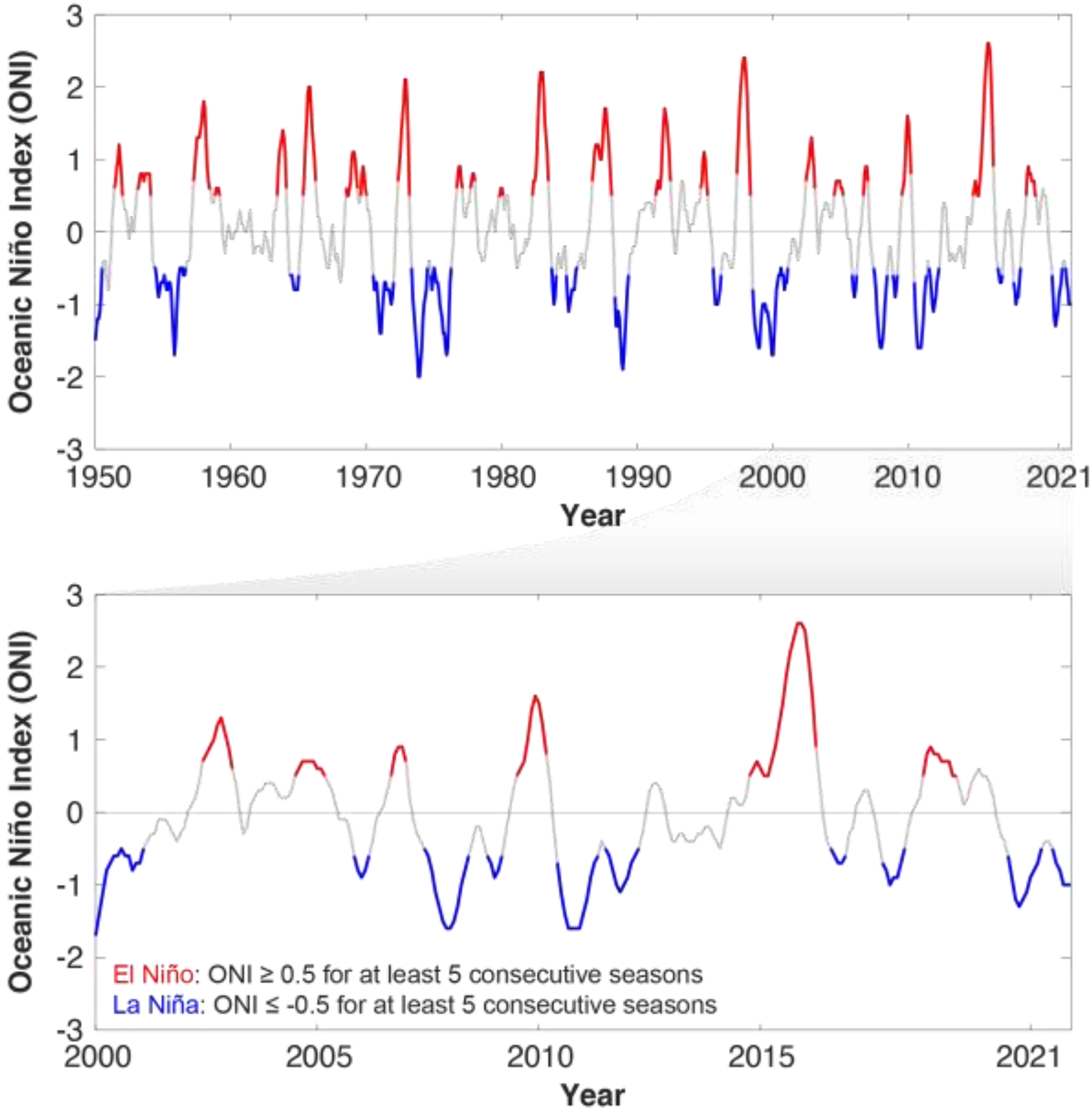

Figure 12. Oceanic Niño Index from 1950–2021 (top) and 2000–2021 (bottom) with El Niño periods in red and La Niña periods in blue

2.4.3.4 Pacific Decadal Oscillation

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

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

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

Timeframe: Annual, monthly.

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

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

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

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

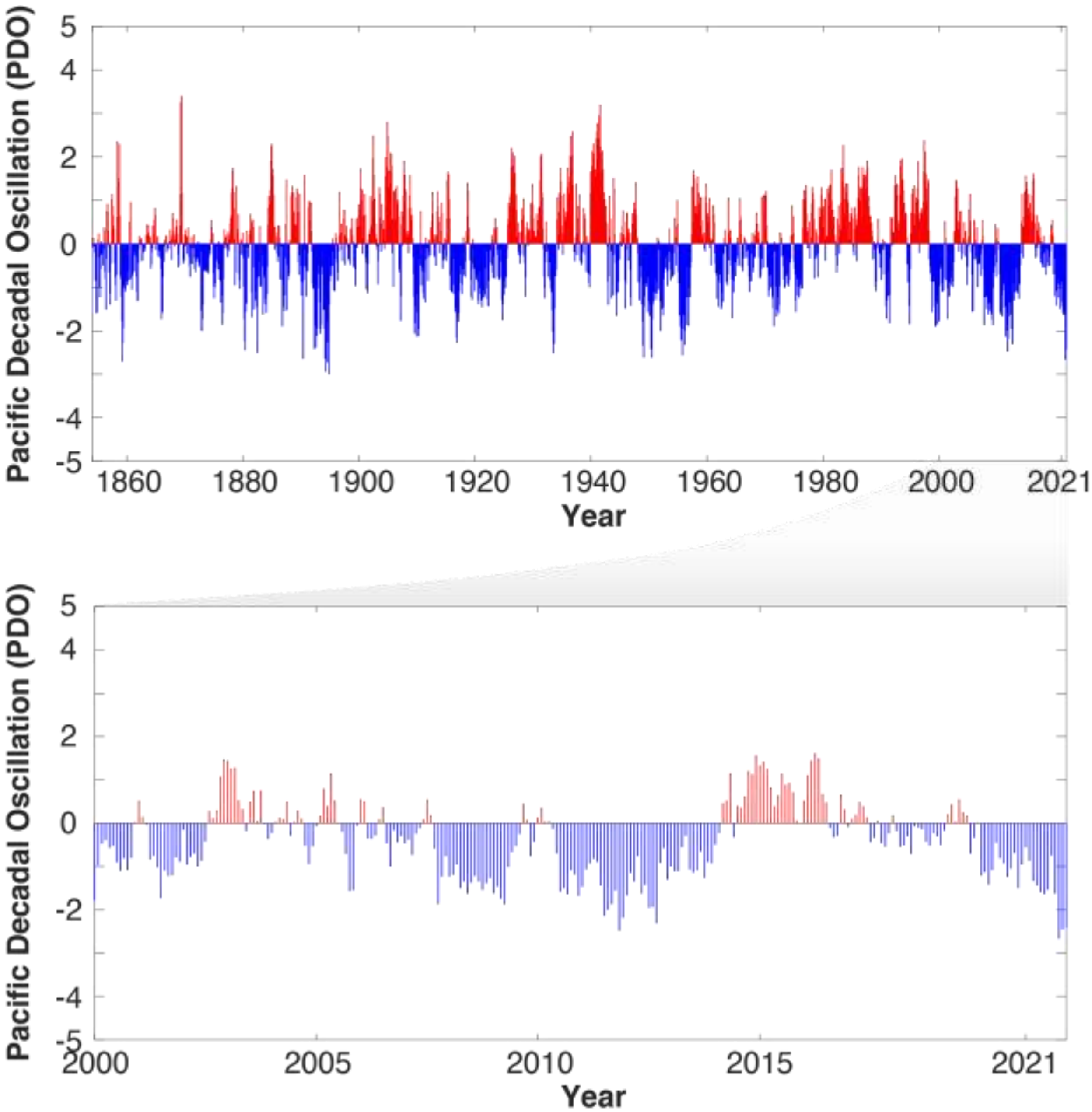

Figure 13. Pacific Decadal Oscillation from 1950–2021 (top) and 2000–2021 (bottom) with positive warm periods in red and negative cool periods in blue

2.4.3.5 Tropical Cyclones

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

Status:

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

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

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

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

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

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

The annual frequency of storms passing through each basin is tracked and Figure 14 shows the representative breakdown of Saffir-Simpson hurricane categories.

Every cyclone has an ACE Index value, which is a number based on the maximum wind speed measured at six-hourly intervals over the entire time that the cyclone is classified as at least a tropical storm (wind speed of at least 34 knots; 39 mph). Therefore, a storm's ACE Index value accounts for both strength and duration. Figure 166 shows the ACE values for each hurricane/typhoon season and has a horizontal line representing the average annual ACE value.

Timeframe: Annual.

Region/Location:

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

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

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

South Pacific: south of the equator.

Measurement Platform: Satellite.

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

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

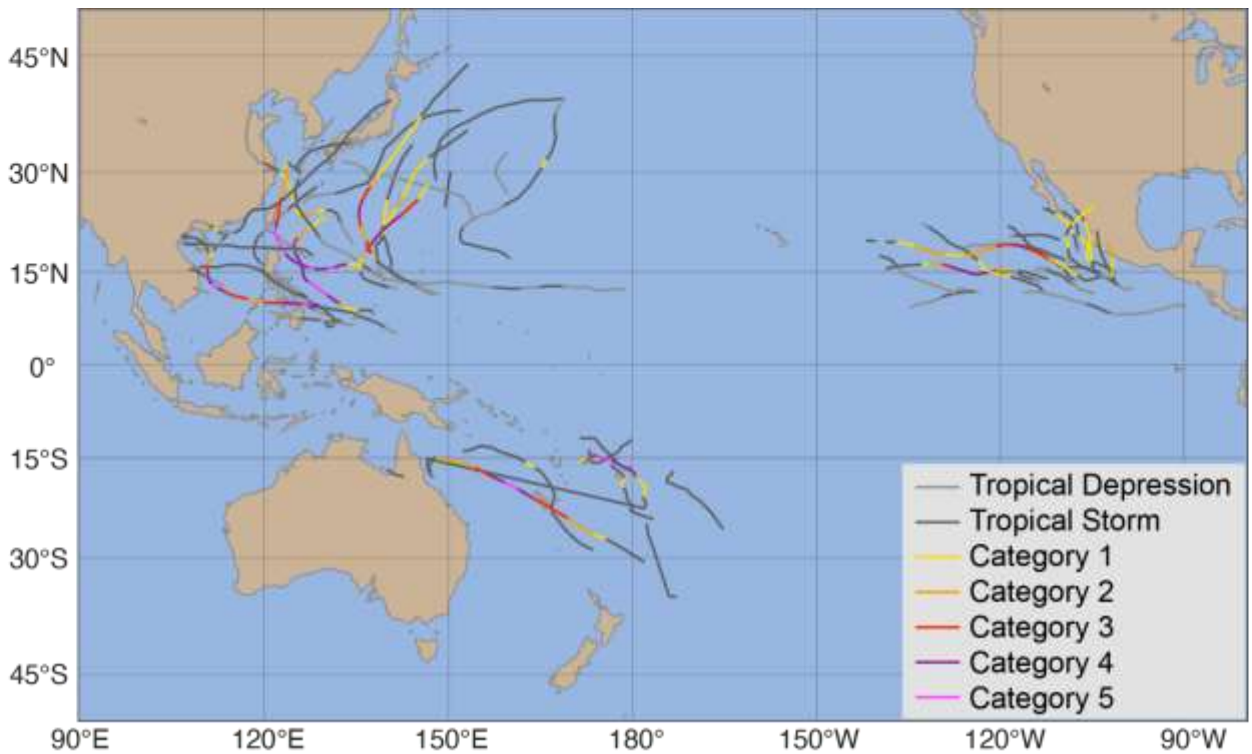

Figure 14. 2021 Pacific basin tropical cyclone tracks

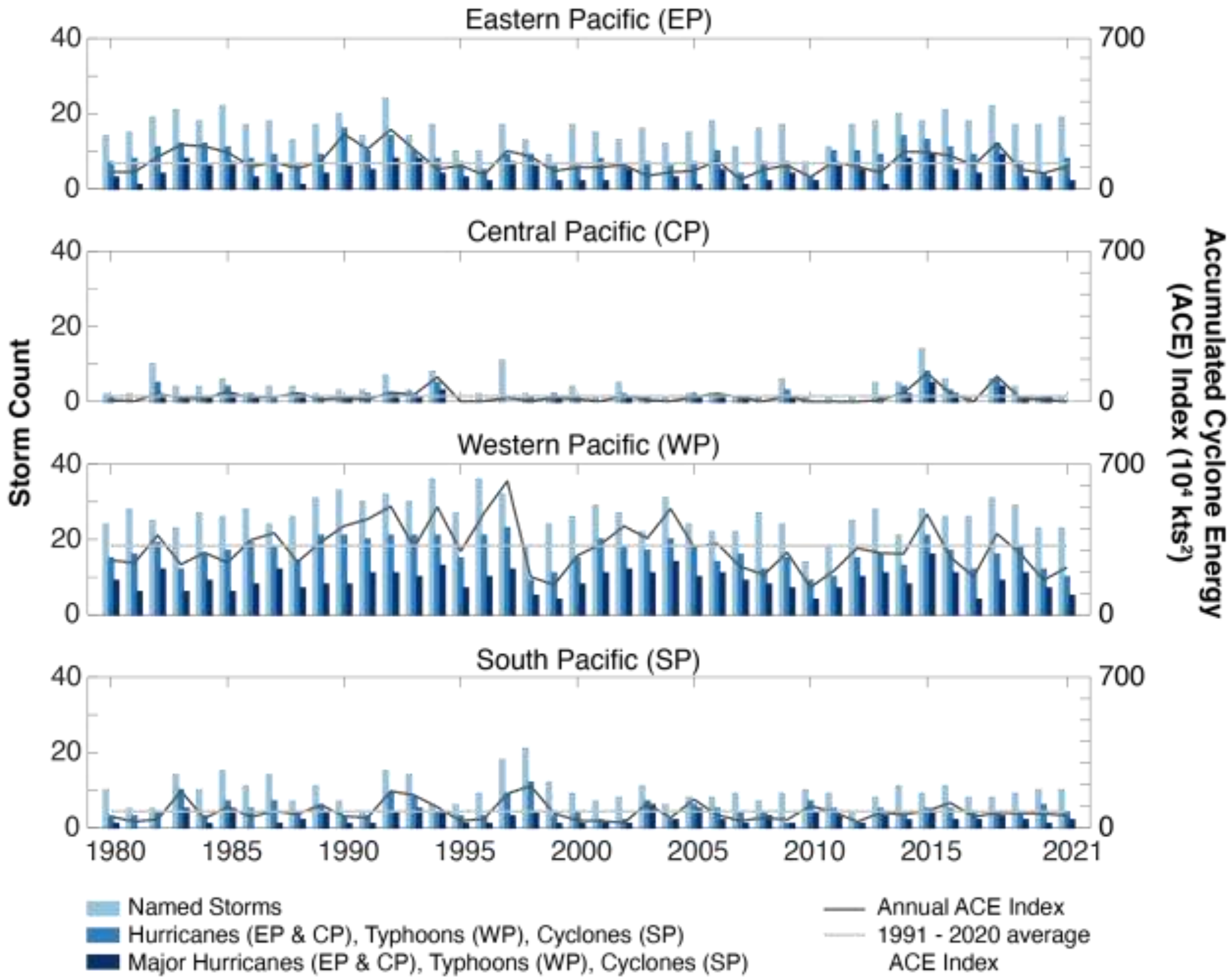

Figure 15. 2021 tropical storm totals by region

2.4.3.6 Sea Surface Temperature and Anomaly

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

Status:

Pacific Remote Island Areas Grid: Annual mean SST was 27.69 ºC in 2021. Over the period of record, monthly SST shows no significant pattern of increase or decrease. Monthly SST values in 2021 ranged from 26.61 – 28.44 ºC, within the climatological range of 25.70 – 30.10 ºC. The annual anomaly was -0.42 ºC cooler than average, with positive anomaly values in the northern part of the region.

Johnston Atoll Grid: Annual mean SST was 26.84 ºC in 2021. Over the period of record, annual SST has increased at a rate of 0.017 ºC yr^{-1}. Monthly SST values in 2021 ranged from 25.82 – 27.98 ºC, within the climatological range of 24.56 – 29.31 ºC. The annual anomaly was 0.15 ºC hotter than average.

Wake Atoll Grid: Annual mean SST was 28.09 ºC in 2021. Over the period of record, annual SST has increased at a rate of 0.0277 ºC yr^{-1}. Monthly SST values in 2021 ranged from 26.95 – 29.42 ºC, within the climatological range of 24.77 – 30.06 ºC. The annual anomaly was 0.51 ºC hotter than average.

Note that from the top to bottom in Figure 16, Figure 17, and Figure 18, panels show climatological SST (1985–2020), 2021 SST anomaly, time series of monthly mean SST, and time series of monthly SST anomaly.

Description: Satellite remotely-sensed monthly sea surface temperature (SST) is averaged across each of the PRIA Grid (1°S – 7°N, 159° – 177°W; including Howland, Baker, Jarvis, Palmyra, Kingman Reef), Johnston Island (16° – 17°N, 168° – 170°W), and Wake Atoll (17.7° – 20.7°N, 165° – 168°W). Time series of monthly mean SST averaged over the respective grids are presented. Additionally, spatial climatology and anomalies are shown. Data from NOAA Coral Reef Watch CoralTemp v3.1.

Timeframe: Monthly.

Region/Location: PRIA Grid (1°S – 7°N, 159° – 177°W); Johnston Atoll (16° – 17°N, 168° – 170°W), and Wake Atoll (17.7° – 20.7°N, 165° – 168°W)

Measurement Platform: Satellite.

Sourced from: NOAA OceanWatch (2022a).

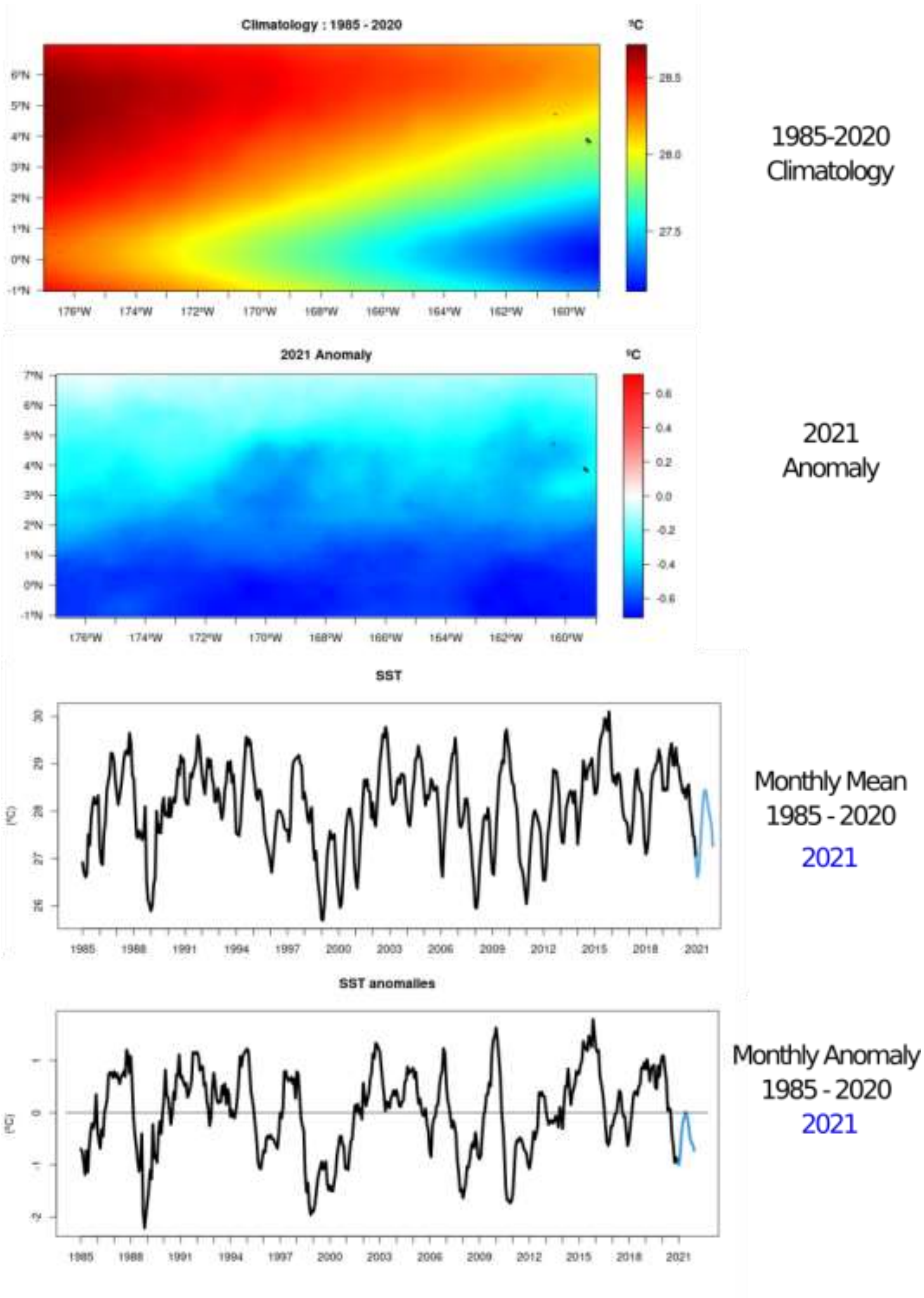

Figure 16. Sea surface temperature climatology and anomalies from the PRIA Grid

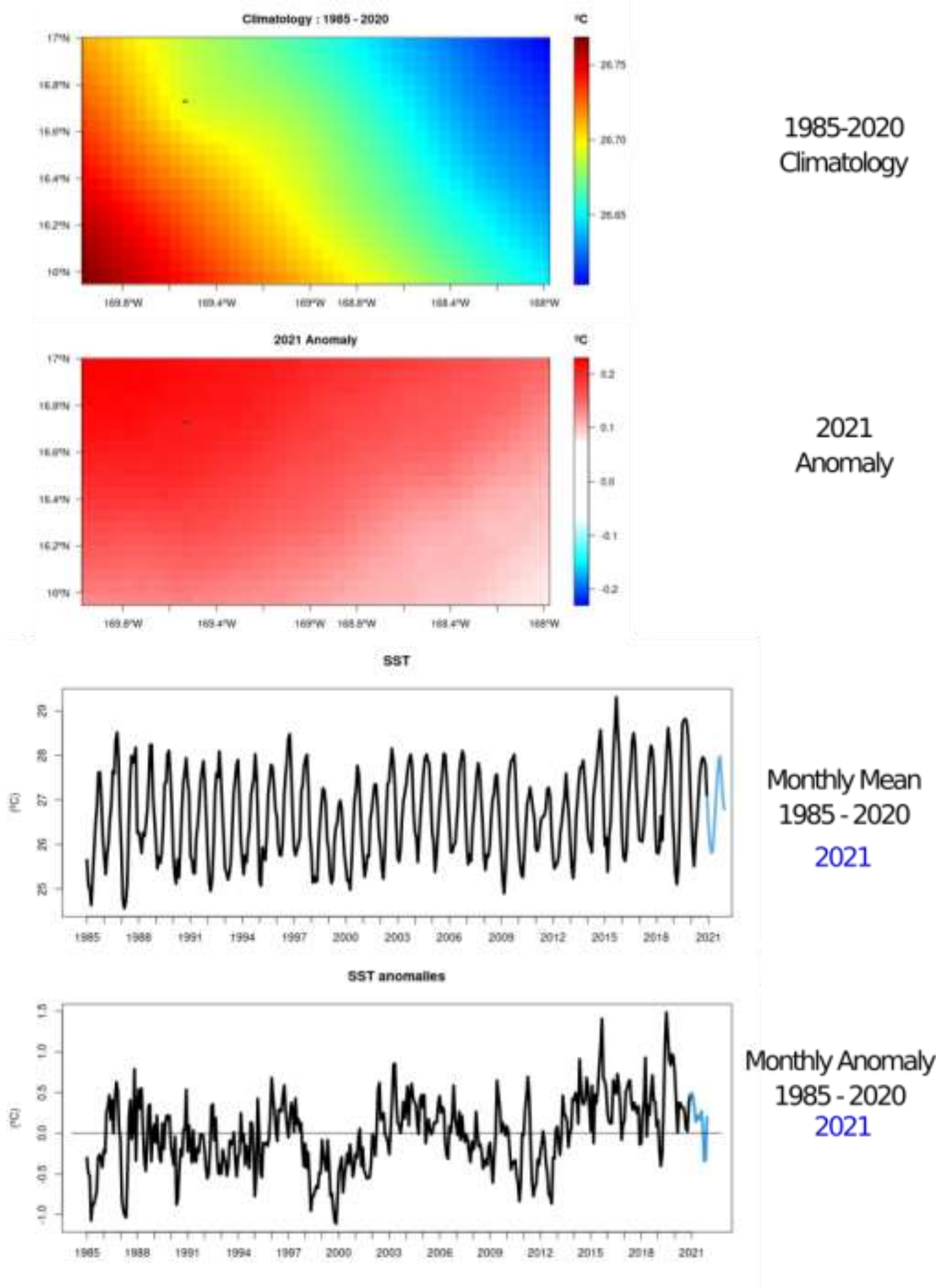

Figure 17. Sea surface temperature climatology and anomalies from Johnston Atoll Grid

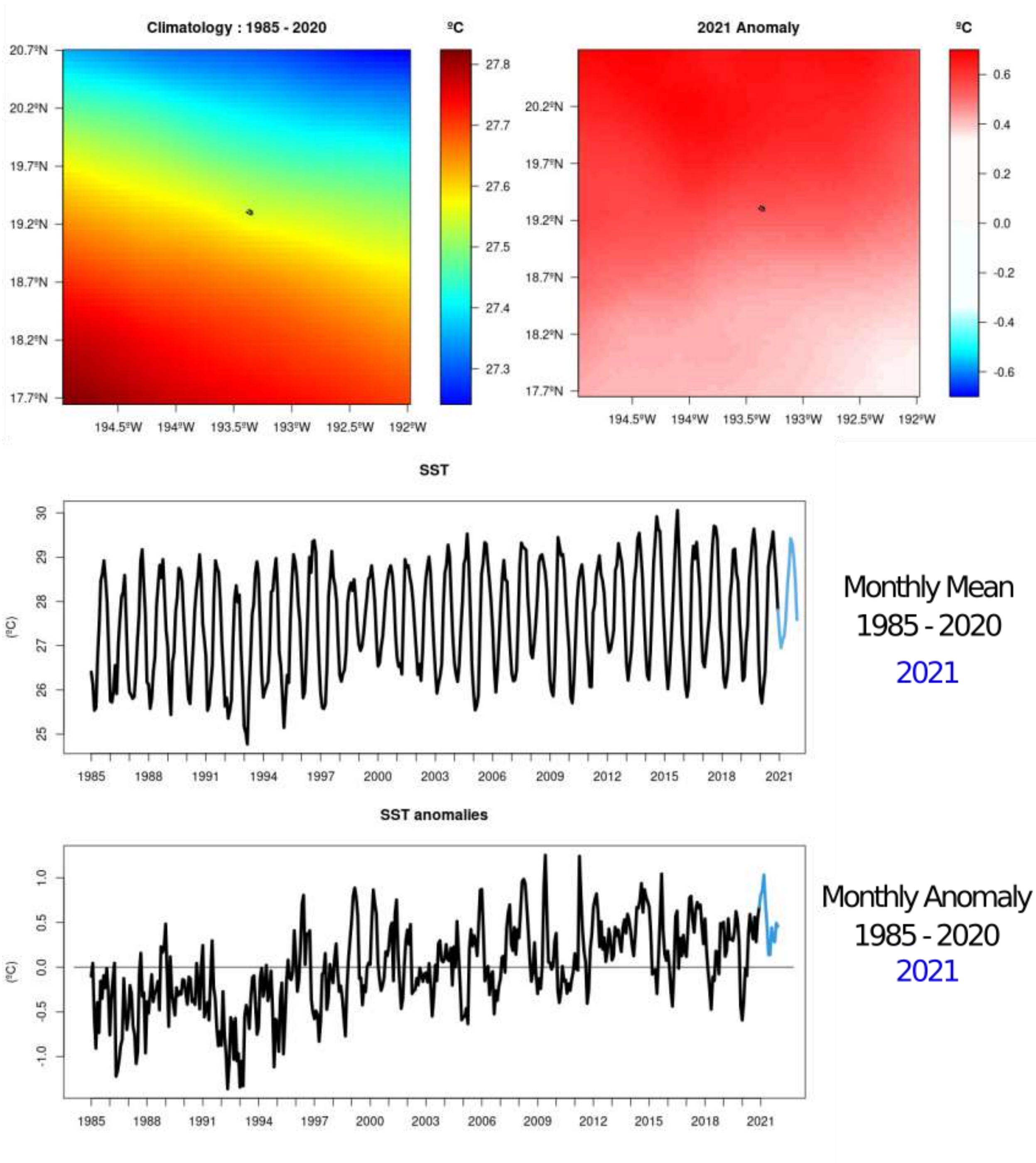

Figure 18. Sea surface temperature climatology and anomalies from Wake Atoll Grid

2.4.3.7 Coral Thermal Stress Exposure: Degree Heating Weeks

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

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

Status: After experiencing major heat stress events in 2015–2016 and 2019, only Wake Atoll experienced another minor heat stress event in 2021.

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

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

Timeframe: 2014–2021, Daily data.

Region/Location: Global.

Sourced from: NOAA Coral Reef Watch (2022).

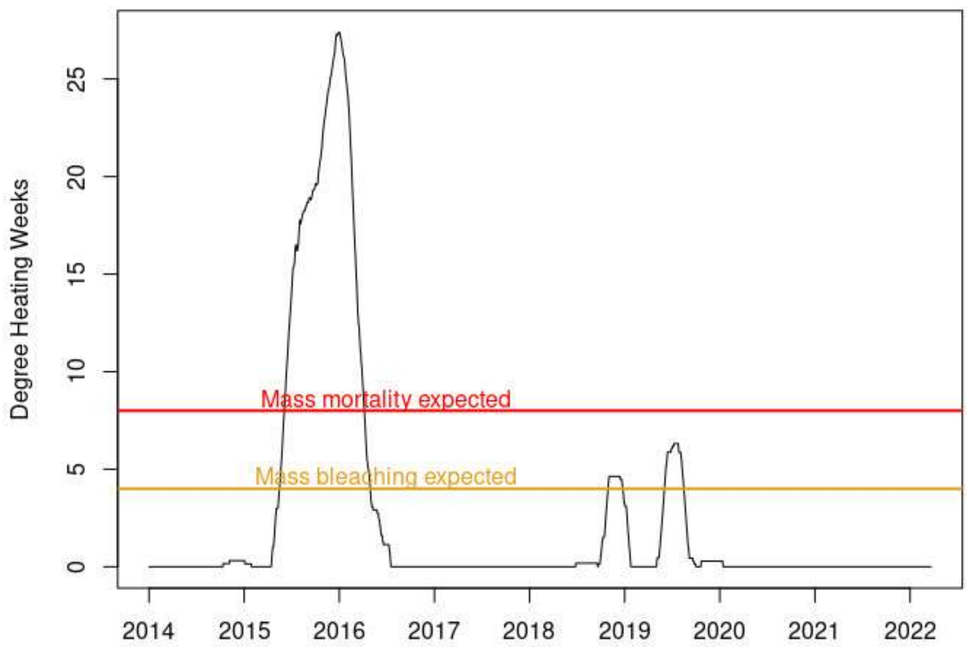

Figure 19. Coral Thermal Stress Exposure, Northern Line Islands Virtual Station 2014–2021 (Coral Reef Watch Degree Heating Weeks)

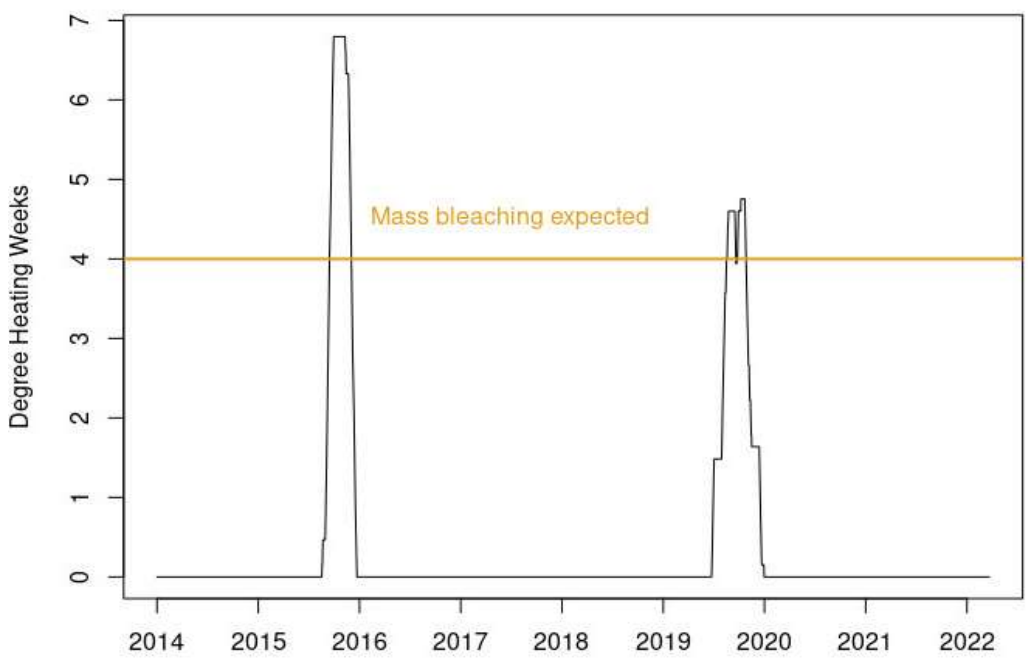

Figure 20. Coral Thermal Stress Exposure, Johnston Atoll Virtual Station 2014–2021 (Coral Reef Watch Degree Heating Weeks)

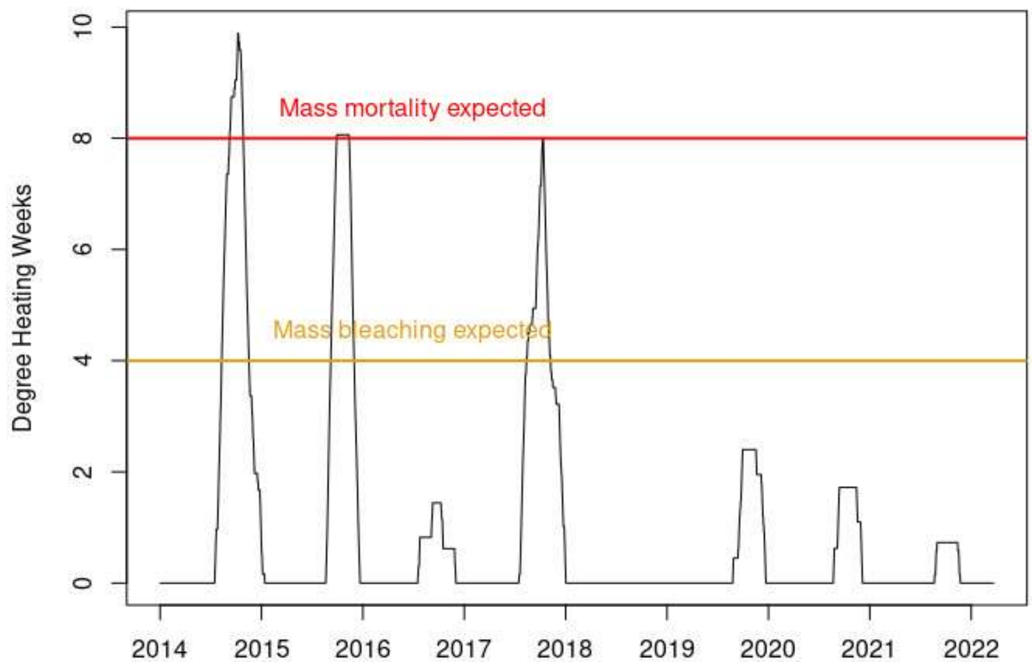

Figure 21. Coral Thermal Stress Exposure, Wake Atoll Virtual Station 2014–2021 (Coral Reef Watch Degree Heating Weeks)

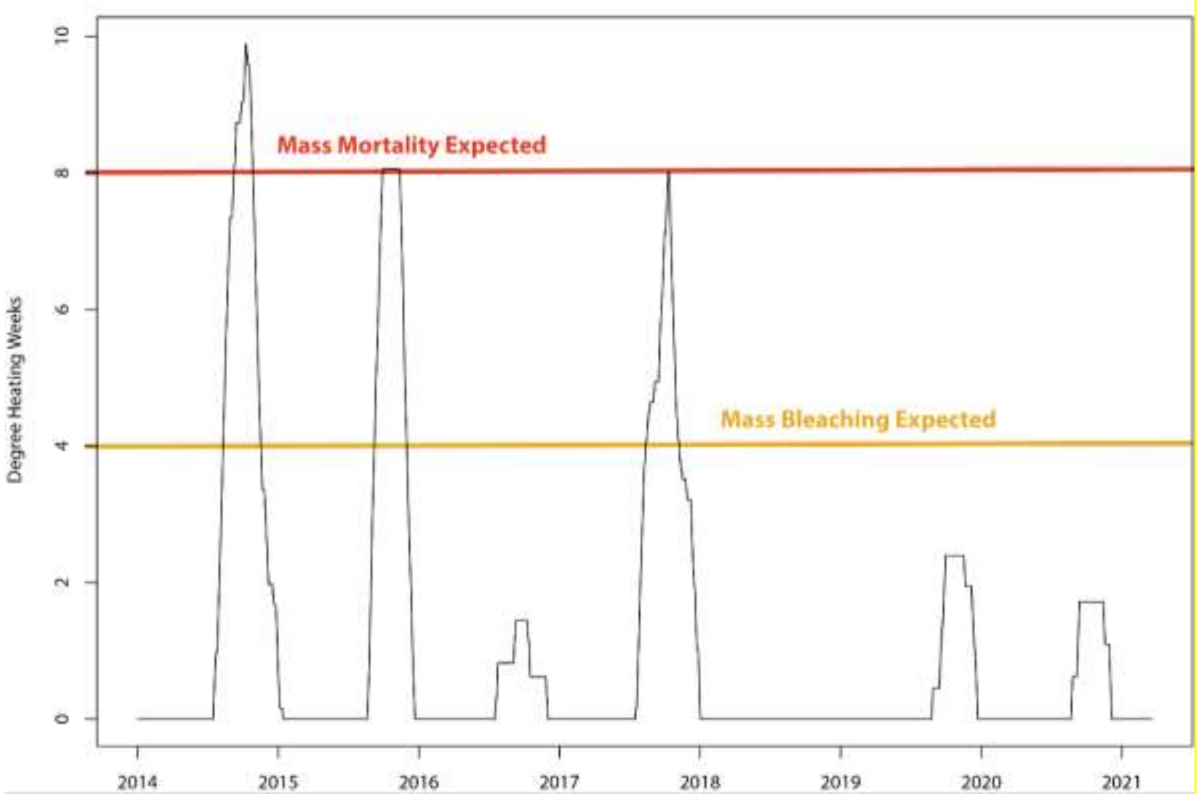

Figure 22. Coral Thermal Stress Exposure, Howland and Baker Virtual Station 2014–2021 (Coral Reef Watch Degree Heating Weeks)

2.4.3.8 Chlorophyll-A and Anomaly

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

Status:

Pacific Remote Island Areas: Annual mean Chl-A was 0.189 mg/m^3 in 2020. Over the period of record, annual Chl-A has shown a significant linear decrease at a rate of 0.001 mg/m^3. Monthly Chl-A values in 2020 ranged from 0.163–0.216 mg/m^3, within the climatological range of 0.064 – 0.278 mg/m^3. The annual anomaly was 0.0084 mg/m^3 higher than climatological values, with negative values in the northern part of the region.

Johnston Atoll: Annual mean Chl-A was 0.055 mg/m^3 in 2020. Over the period of record, annual Chl-A has shown a significant linear decrease at a rate of 0.00025 mg/ m^3. Monthly Chl-A values in 2020 ranged from 0.043–0.081 mg/m^3, within the climatological range of 0.043 – 0.10 mg/m^3. The annual anomaly was 0.0042 mg/m^3 lower than climatological values, with positive values toward the northeastern part of the atoll.

Wake Atoll: Annual mean Chl-A was 0.043 mg/m^3 in 2020. Over the period of record, annual Chl-A has shown a weakly significant linear decrease at a rate of 0.0002 mg/ m^3. Monthly Chl-A values in 2020 ranged from 0.036–0.052 mg/m^3, within the climatological range of 0.035 – 0.128 mg/m^3. The annual anomaly was 0.0072 mg/m^3 lower than climatological values.

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

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

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

Region/Location: Global.

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

Sourced from: NOAA OceanWatch (2022b).

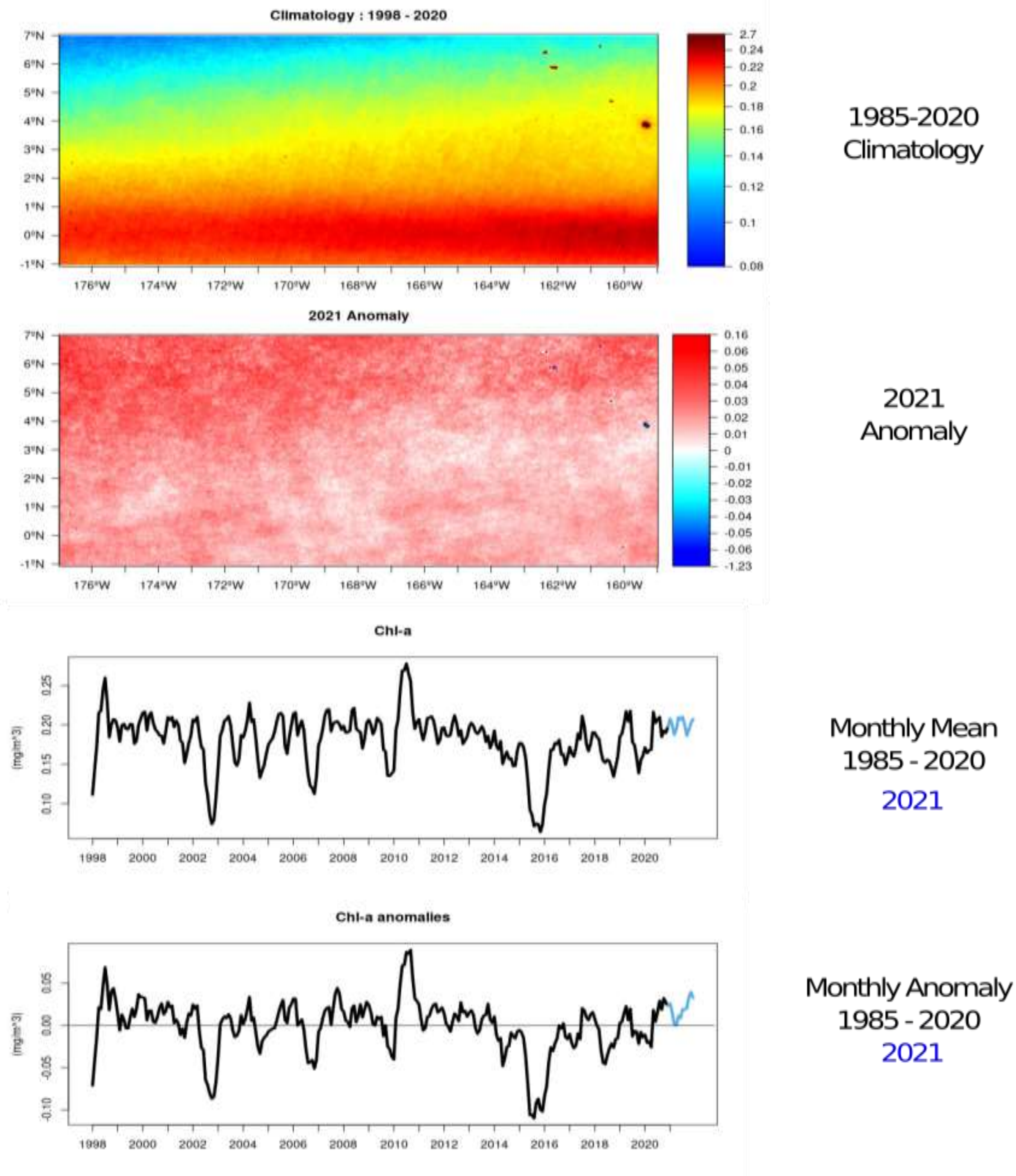

Figure 23. Chlorophyll-*a* and Chlorophyll-*a* Anomaly from the PRIA Grid

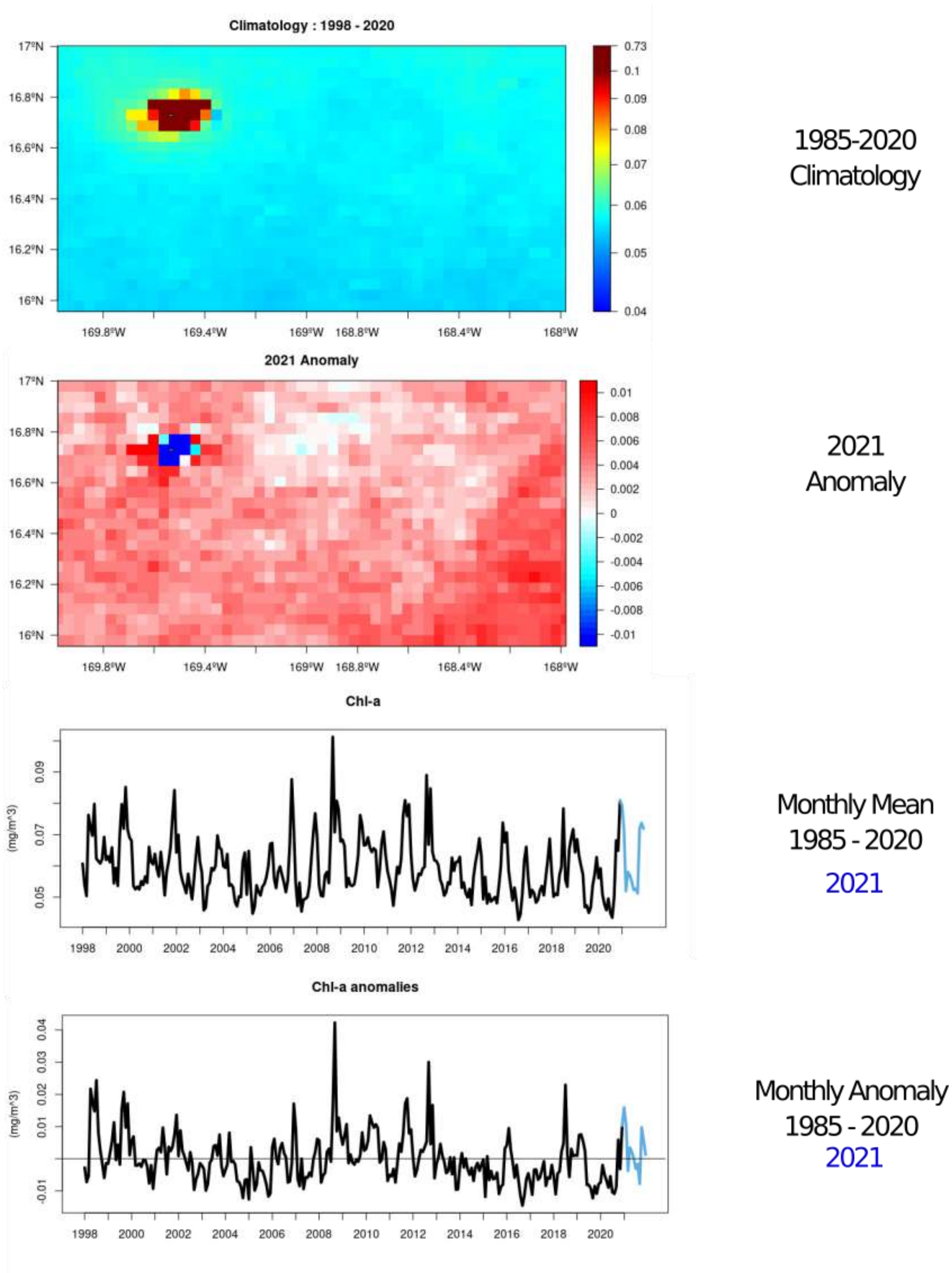

Figure 24. Chlorophyll-*a* and Chlorophyll-*a* Anomaly from the Johnston Atoll Grid

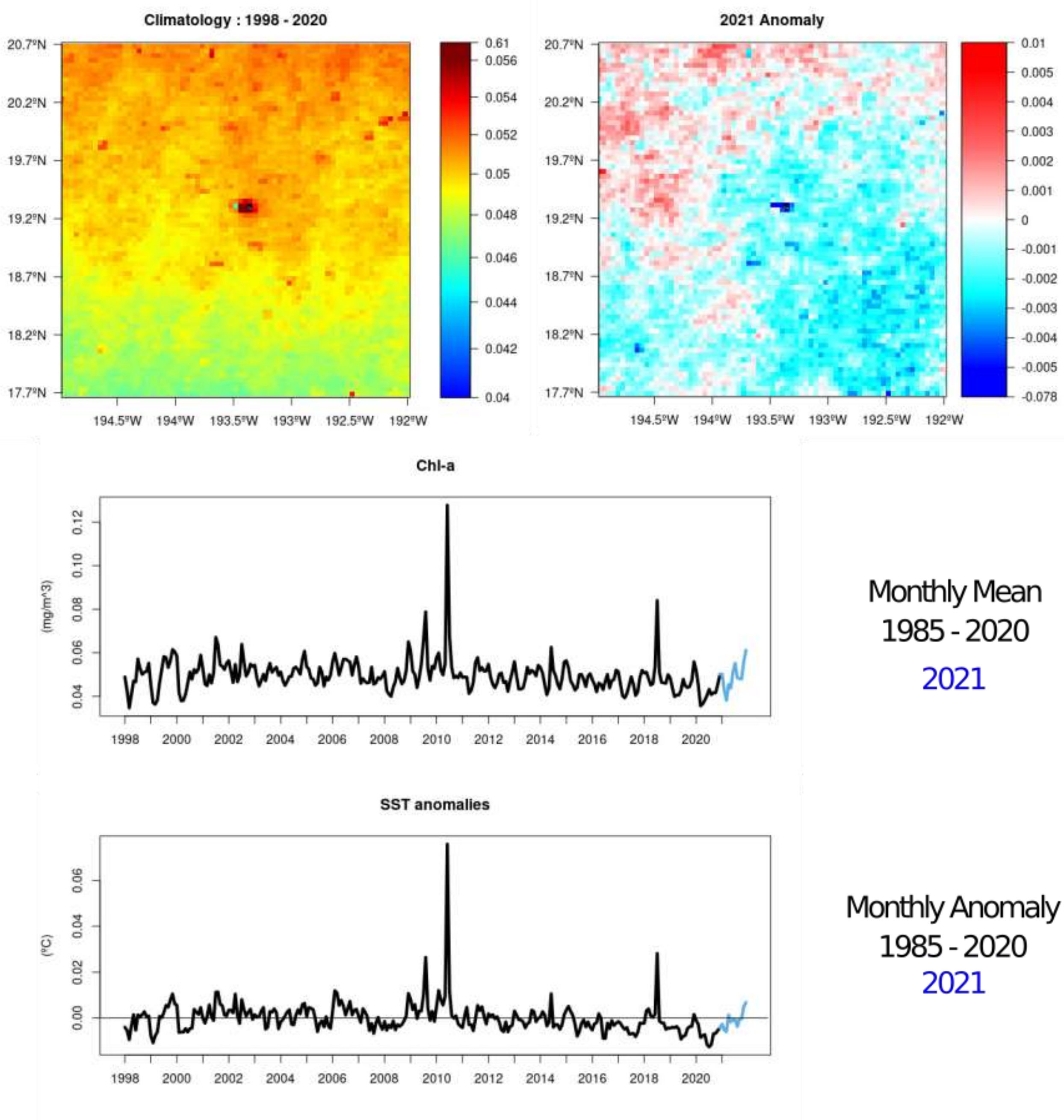

Figure 25. Chlorophyll-*a* and Chlorophyll-*a* Anomaly from the Wake Atoll Grid

2.4.3.9 Rainfall

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

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

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

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the rain gauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988). Here the data output from step 1 is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude.

Timeframe: Monthly.

Region/Location: Global.

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

Source: APDRC (2022).

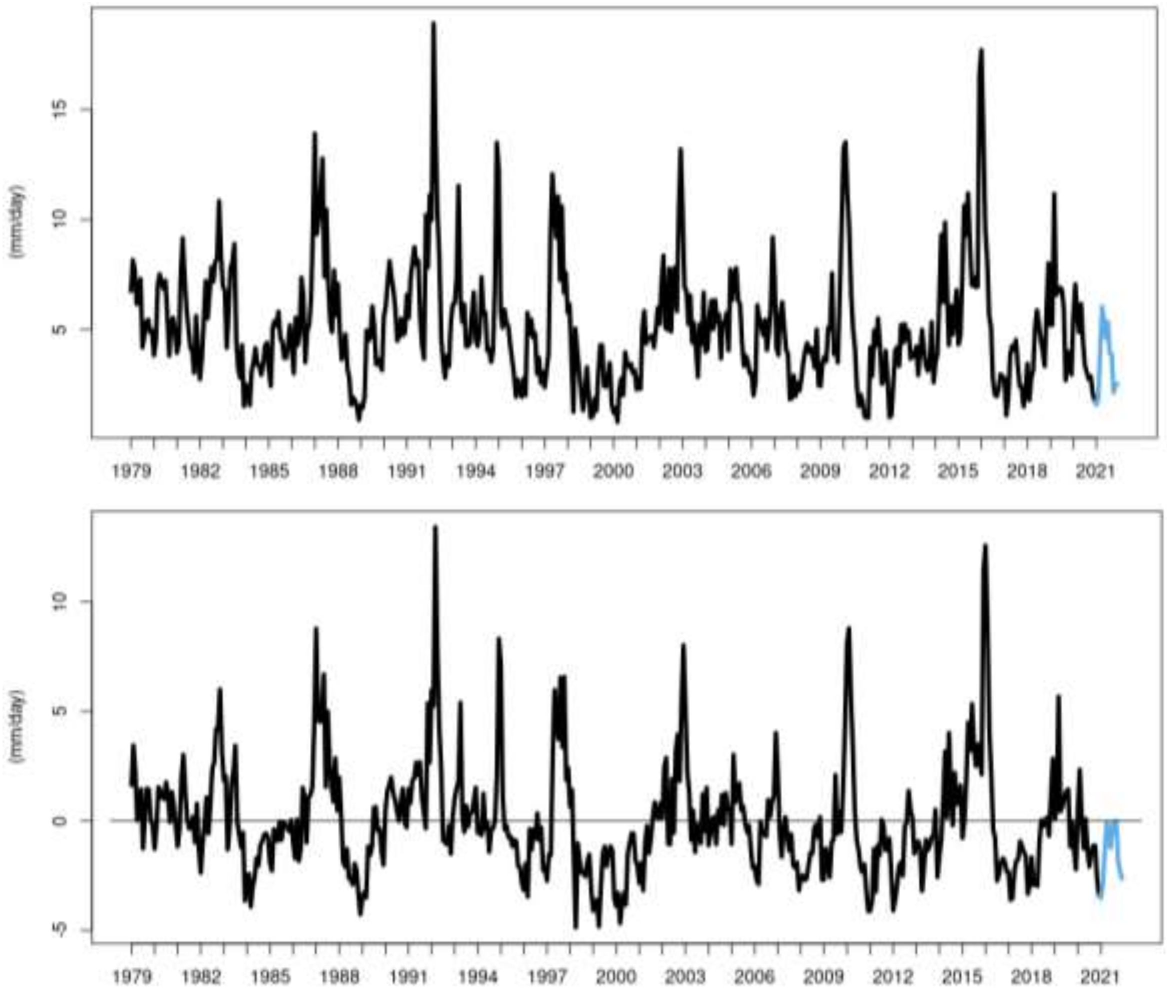

Figure 26. CMAP precipitation (top) and anomaly (bottom) across the PRIA Grid with 2021 values in blue

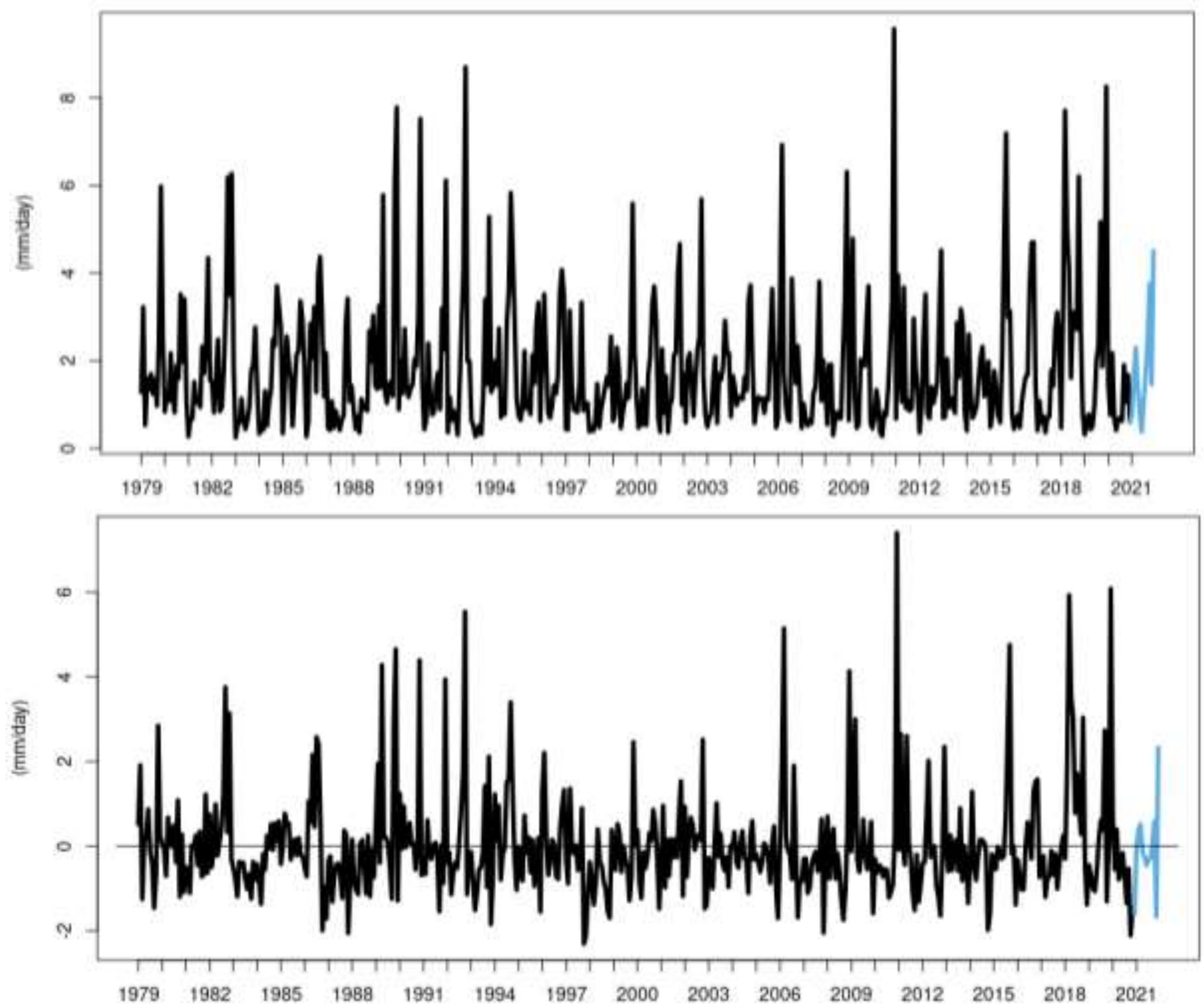

Figure 27. CMAP precipitation (top) and anomaly (bottom) across the Johnston Atoll Grid with 2021 values in blue

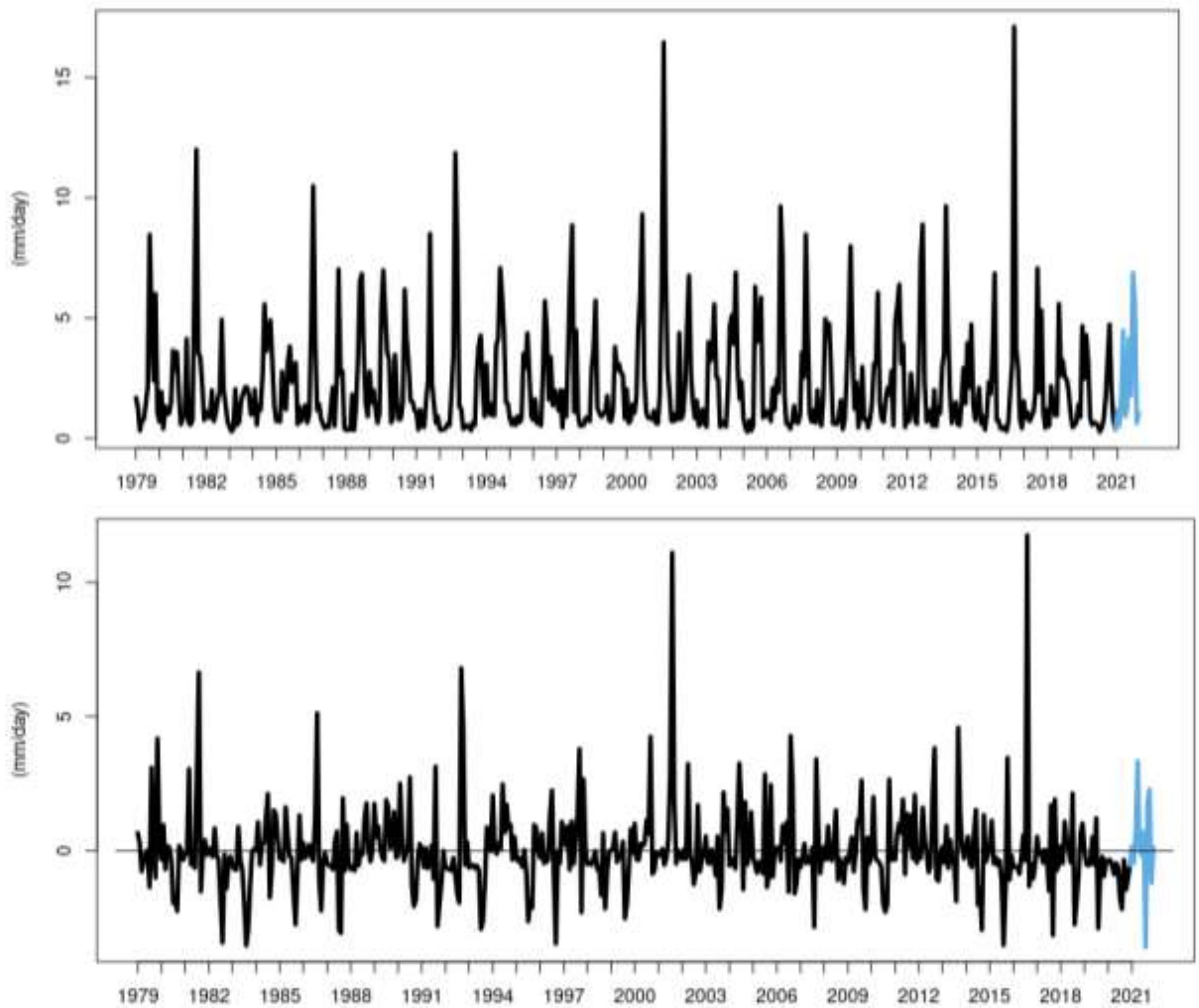

Figure 28. CMAP precipitation (top) and anomaly (bottom) across the Wake Atoll Grid with 2021 values in blue

2.4.3.10 Sea Level (Sea Surface Height and Anomaly)

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

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

Timeframe: Monthly.

Region/Location: Observations from selected sites across the Western Pacific.

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

Source: Aviso (2022), NOAA CoastWatch (2022), and NOAA (2022e).

2.4.3.10.1 Basin-Wide Perspective

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

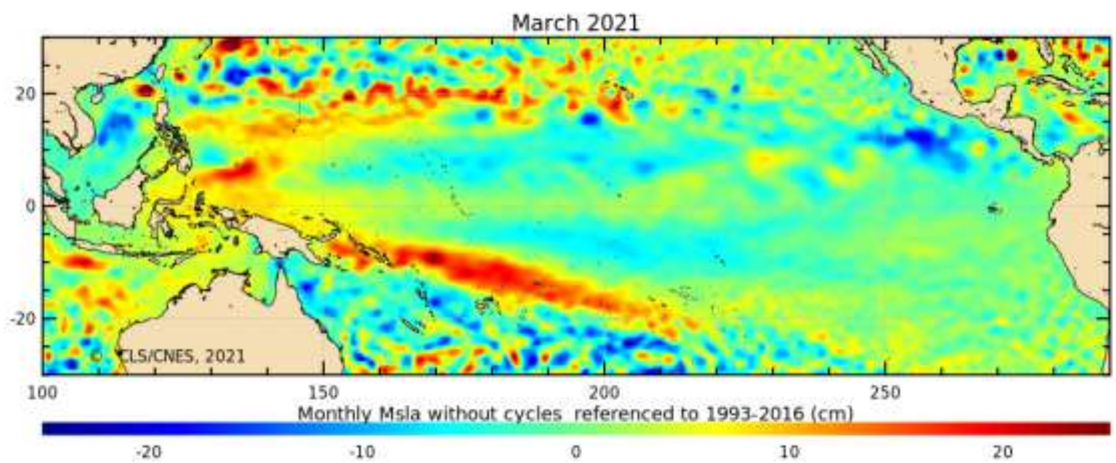

Figure 29a. Sea surface height and anomaly across the Pacific Ocean

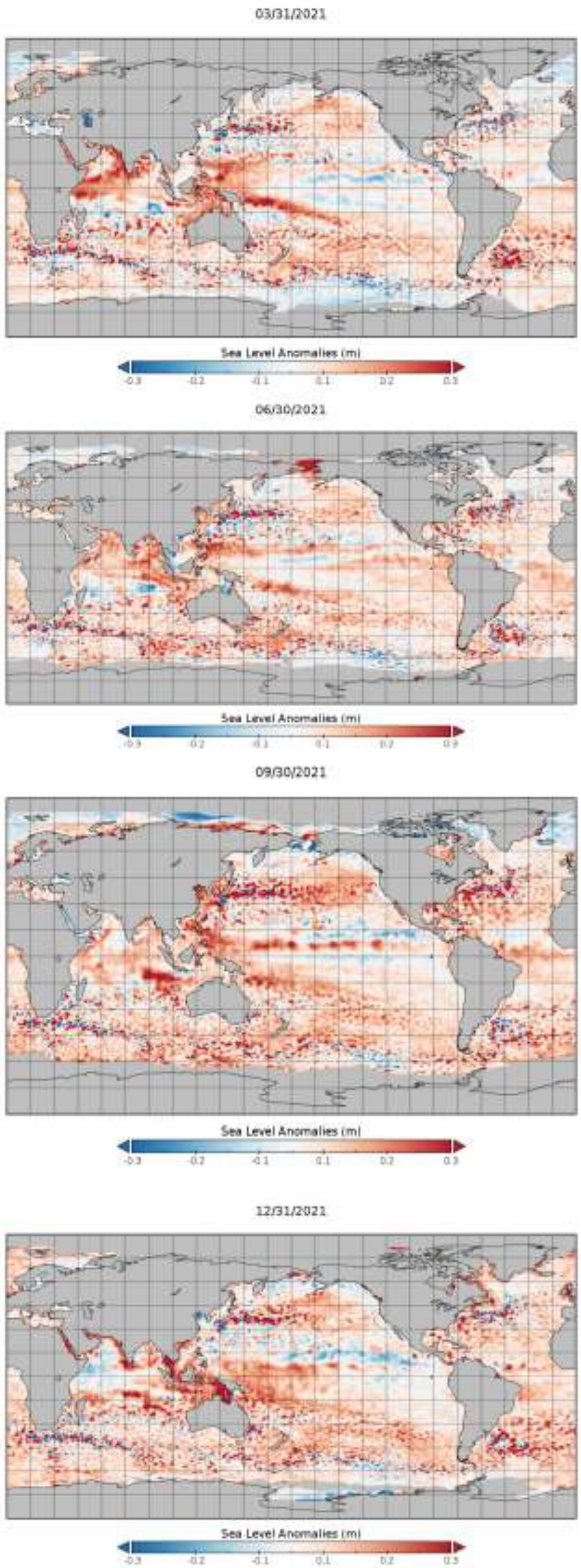

Figure 29b. Quarterly time series of mean sea level anomalies during 2021.

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

2.4.3.10.2 Local Sea Level

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

The following figures and descriptive paragraphs were inserted from NOAA Tides and Currents website. Figure 30 shows the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The calculated trends for all stations are available as a table in millimeters/year and in feet/century. If present, solid vertical lines indicate times of any major earthquakes in the vicinity of the station and dashed vertical lines bracket any periods of questionable data or datum shift.

The relative sea level trend is 2.16 millimeters/year with a 95% confidence interval of +/- 0.4 mm/yr based on monthly mean sea level data from 1950 to 2021, which is equivalent to a change of 0.71 feet in 100 years (Figure 30).

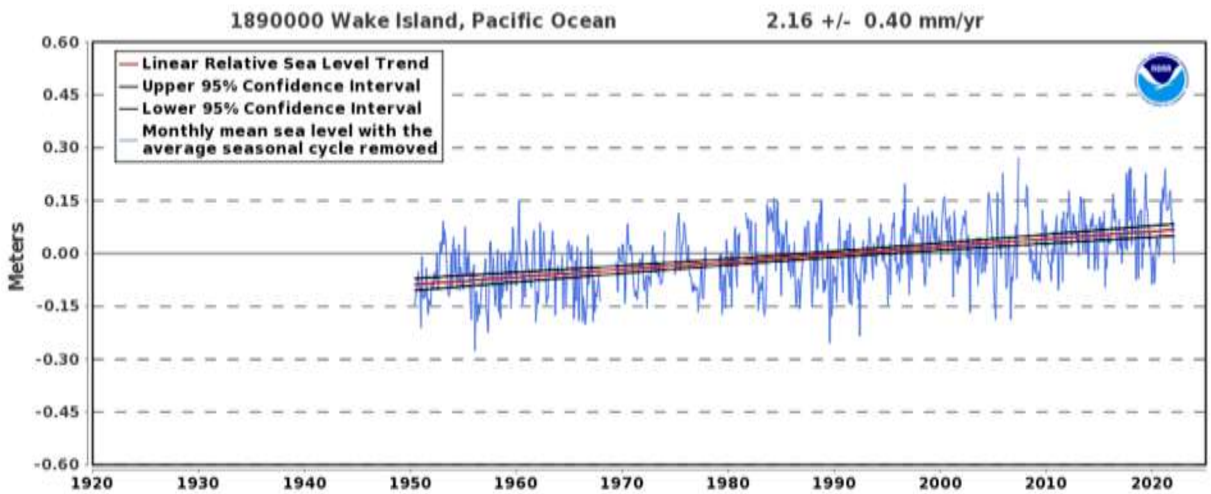

Figure 30. Monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents at Wake Island

2.5 ESSENTIAL FISH HABITAT

2.5.1 Introduction

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

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

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

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

2.5.1.1 EFH Information

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

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

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

- Updated species descriptions, which can be found appended to previous SAFE reports and can be used to directly update the FEP;
- Updated EFH levels of information tables, which can be found in Section 2.5.5;
- Updated research and information needs, which can be found in Section 2.5.6 and can be used to directly update the FEP; and
- An analysis that distinguishes EFH from all potential habitats used by the species, which is the basis for an options paper for the Council and can be developed if enough information exists to refine EFH.

2.5.1.2 Habitat Objectives of FEP

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

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

The annual reports have reviewed the precious coral EFH components, crustacean EFH component, and non-fishing impacts components. The Council's support of non-fishing activities research is monitored through the program plan and Five-Year Research Priorities, not the annual report.

2.5.1.3 Response to Previous Council Recommendations

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

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

2.5.2 Habitat Use by MUS and Trends in Habitat Condition

The PRIA comprise the U.S. possessions of Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Kingman Reef, Wake Island, Palmyra Atoll, and Midway Atoll (Figure 31). However, because Midway is located in the Hawaiian archipelago, it is included in the Hawaii

Archipelago FEP[1]. Therefore, PRIA does not include Midway Atoll for the purpose of federal fisheries management.

Baker Island is part of the Phoenix Islands archipelago. It is located approximately 1,600 nautical miles (nm) 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 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 nm 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 nm 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 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 nm southwest of Honolulu. French Frigate Shoals in the NWHI, about 450 nm 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 Marine National Monument (PRIMNM), which is 50 nm surrounding Palmyra Atoll and Kingman Reef and Howland and Baker Islands, and the entire US EEZ surrounding Johnston Atoll, Wake, and Jarvis Island.

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

Essential fish habitat in the PRIA for the four MUS comprises all substrate from the shoreline to the 700 m isobath (Figure 32). 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. PIFSC CRED was replaced by the Coral Reef Ecosystem Program (CREP) within the PIFSC Ecosystem Sciences Division (ESD) before being shifted to the Archipelagic Research Program (ARP).

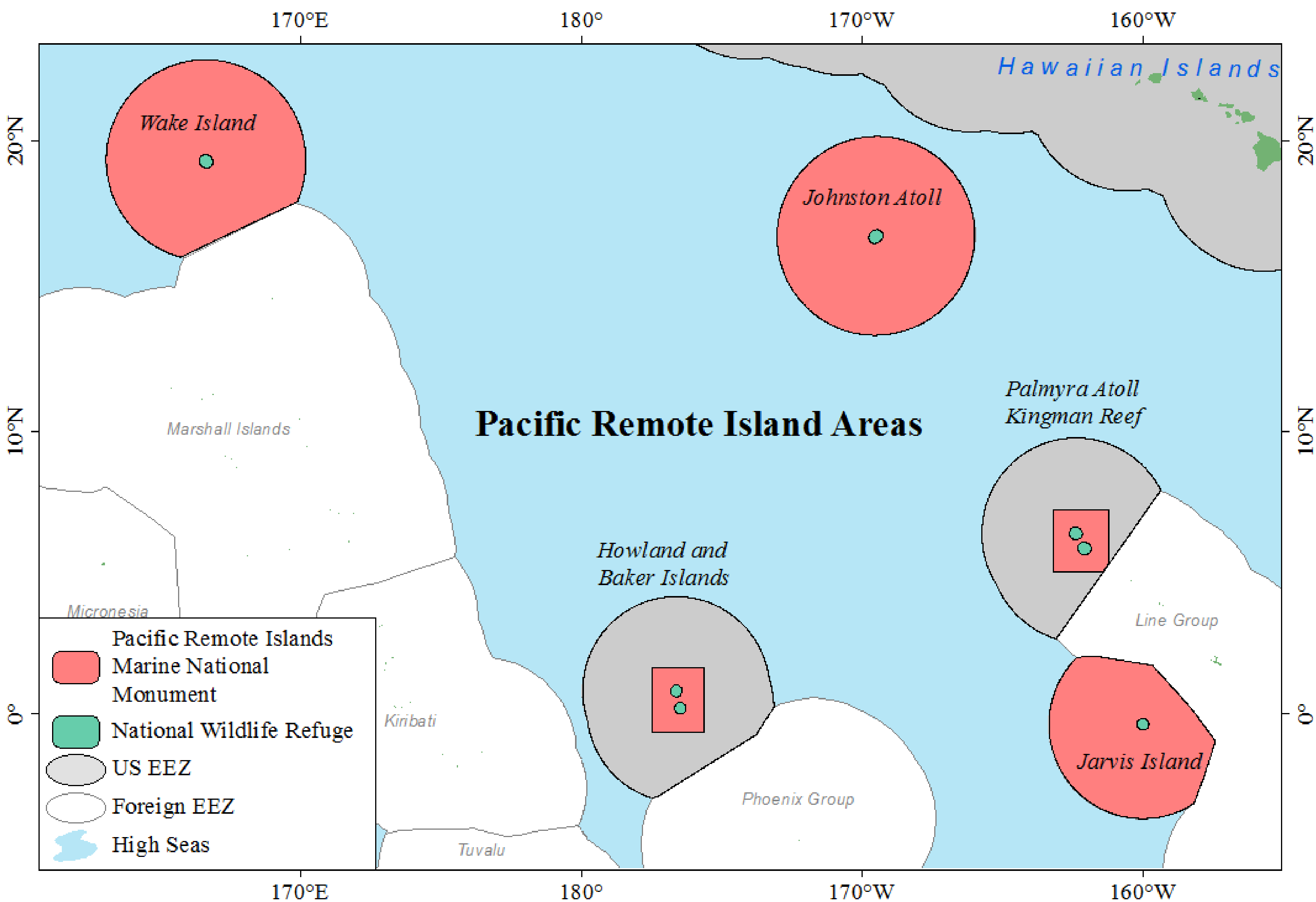

Figure 31. Pacific Remote Island Areas and the associated Pacific Remote Islands Marine National Monument

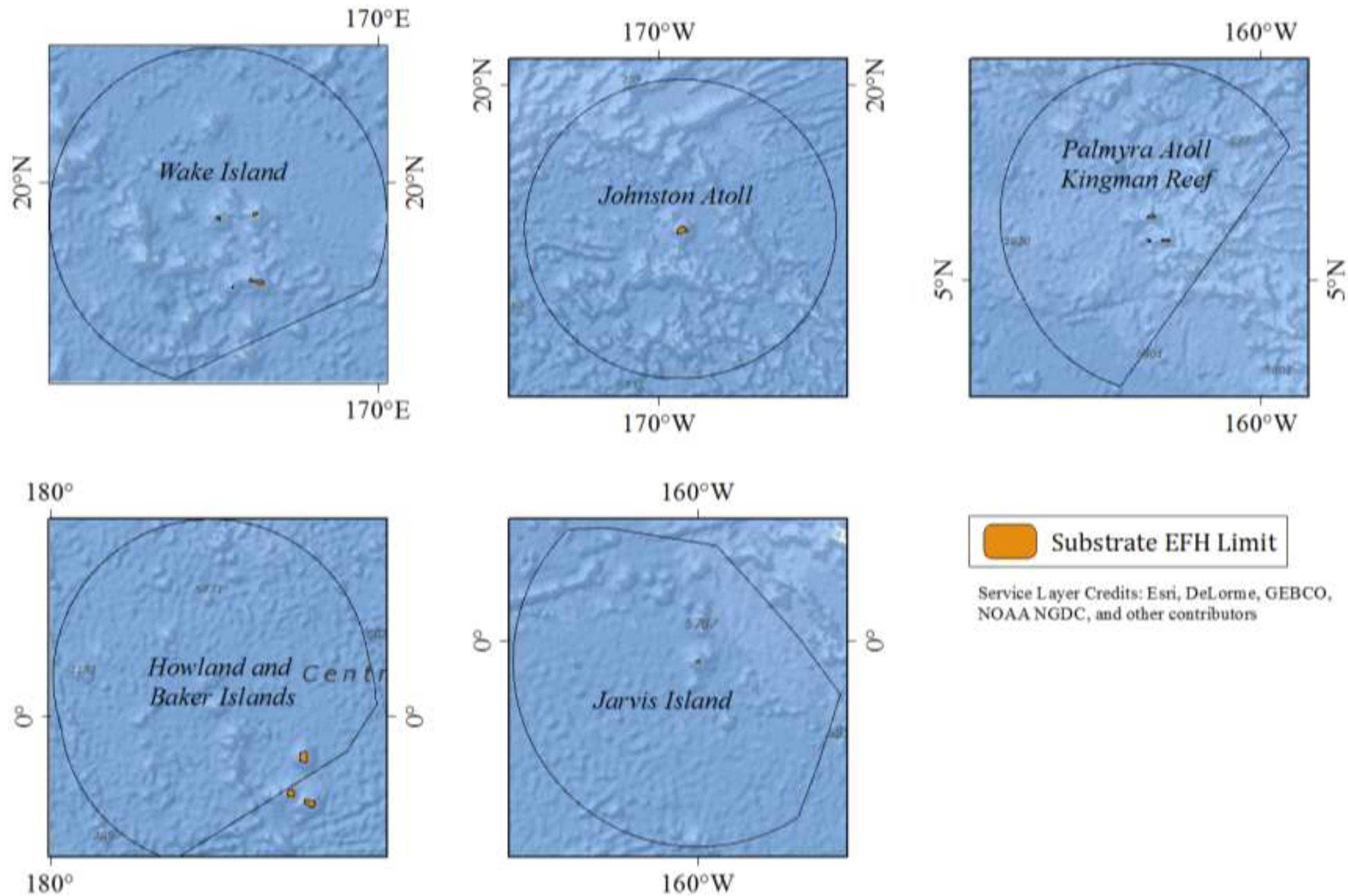

Figure 32. The substrate EFH limit and 700-meter isobath around the PRIA (from Ryan et al. 2009)

2.5.2.1 Habitat Mapping

No new data were collected in the PRIA in 2021 that would enable updates to habitat use by MUS or trends in habitat condition.

2.5.2.2 Benthic Habitat

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

2.5.2.2.1 RAMP Indicators

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

2.5.2.3 Oceanography, Water Quality, and Other Environmental Data

The water column is also designated as EFH for selected MUS life stages at various depths. For larval stages of all species except deepwater shrimp, the water column is EFH from the shoreline to the EEZ. Coral reef species egg and larval EFH is to a depth of 100 m; crustaceans, 150m; and bottomfish, 400 m. Please see the Climate and Oceanic Indicators section (Section 2.4) for information related to oceanography and water quality. While no substantial field research data efforts occurred in 2021, satellite and buoy data are continuously collected and archived. PIFSC staff recently developed an advanced data compilation tool, the Environmental Data Summary (EDS), that gives users a simple, consistent way to enhance existing *in situ* observations with external gridded environmental data. The EDS is written in R and provides users an interface to NOAA CoastWatch and OceanWatch datasets through the ERDDAP server protocol. The EDS allows users to download, filter, and/or extract large amounts of gridded and tabular data given user-defined time stamps and geographical coordinates. The various external environmental data summarized at individual survey sites can aid scientists in assessing and understanding how environmental variabilities impact living marine resources. The EDS outputs were summarized at the National Coral Reef Monitoring Program (NCRMP) Rapid Ecological Assessment (REA) site level from 2000 to 2020 across 57 islands covered by the survey. PIFSC is planning to expand the utility of EDS with a broader range of gridded NOAA CoastWatch and OceanWatch data products (e.g., wave, wind) at finer spatiotemporal scales (e.g., water columns). Target data content includes spatial data (e.g., remote sensing), modeled data (e.g., Regional Ocean Modeling Systems), and socioeconomic data, including human density.

2.5.3 Report on Review of EFH Information

There were no EFH reviews completed in 2021 for the PRIA, however a review of the biological components of crustacean EFH in Guam and Hawaii was finalized in 2019. The non-fishing impacts and cumulative impacts components were reviewed in 2016 through 2017, which can be found in Minton (2017).

2.5.4 EFH Levels

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

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

The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a managed species' life stage. The existing level of data for individual MUS in each fishery are presented in tables per fishery. In subsequent SAFE reports, each fishery section will include the description of EFH method 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.

Levels of EFH Information are presented in this section first with databases that include observations of multiple species, separated by depth, and then by current or former MUS grouping.

2.5.4.1 Precious Corals

EFH for precious corals was originally designated in Amendment 4 to the Precious Corals Fishery Management Plan (64 FR 19067, 19 April 1999) using the level of data found in Table 7. No new data relevant to precious corals EFH in the PRIA were collected in 2021 that would modify these levels of information.

Table 7. Level of EFH information available for the Western Pacific precious coral MUS

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

Species	Pelagic Phase (Larval Stage)	Benthic Phase	Source(s)
Myriopathes ulex (prev. *A. ulex*)	0	1	Opresko (2009); HURL database

2.5.4.2 Bottomfish and Seamount Groundfish

EFH for bottomfish and seamount groundfish was originally designated in Amendment 6 to the Bottomfish and Seamount Groundfish FMP (64 FR 19067, 19 April 1999) using the level of data found in Table 8. To analyze the potential effects of a proposed fishery management action on EFH, one must consider all designated EFH, but research examining depth and habitat requirements for most species is generally lacking (PIFSC 2021). The levels of information available for PRIA bottomfish did not change in 2021.

Table 8. Level of EFH information available for the Western Pacific BMUS and seamount groundfish MUS complex

Life History Stage	Eggs	Larvae	Juvenile	Adult
Aphareus rutilans (red snapper/silvermouth)	0	0	0	1
Aprion virescens (gray snapper/jobfish)	0	0	1	1
Caranx ignobilis (giant trevally/jack)	0	0	1	1
C. lugubris (black trevally/jack)	0	0	0	1
Hypothodus quernus (sea bass)	0	0	1	1
Etelis carbunculus (red snapper)	0	0	1	1
E. coruscans (red snapper)	0	0	1	1
Lethrinus rubrioperculatus (redgill emperor)	0	0	0	1
Lutjanus kasmira (blueline snapper)	0	0	1	1
Pristipomoides auricilla (yellowtail snapper)	0	0	0	1
P. filamentosus (pink snapper)	0	0	1	1
P. flavipinnis (yelloweye snapper)	0	0	0	1
P. seiboldii (pink snapper)	0	0	1	1
P. zonatus (snapper)	0	0	0	1
Variola louti (lunartail grouper)	0	0	0	1
Beryx splendens (alfonsin)	0	1	2	2
Hyperoglyphe japonica (ratfish/butterfish)	0	0	0	1
Pentaceros wheeleri (armorhead)	0	1	1	3

2.5.4.3 Crustaceans

EFH for crustaceans MUS was originally designated in Amendment 10 to the Crustaceans FMP (64 FR 19067, 19 April 1999) using the level of data found in Table 9. EFH definitions were also approved for deepwater shrimp through an amendment to the Crustaceans FMP in 2008 (73 FR 70603, 21 November 2008). No research efforts in 2021 provided data to modify these levels of information.

Table 9. Level of EFH information available for the Western Pacific CMUS complex

Life History Stage	Eggs	Larvae	Juvenile	Adult
Deepwater shrimp (*Heterocarpus* spp.)	2	0	1	2–3
Kona crab (*Ranina ranina*)	1	0	1	1–2

2.5.5 Research and Information Needs

The Council has identified the following scientific data needs to more effectively address the EFH provisions:

2.5.5.1 All FMP Fisheries

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

2.5.5.2 Bottomfish Fishery

- Inventory of marine habitats in the EEZ of the Western Pacific region.
- Data to obtain a better SPR estimate for American Samoa's bottomfish complex.
- Baseline (virgin stock) parameters (catch per unit effort [CPUE], percent immature) for the Guam/CNMI 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.

2.5.5.3 Crustaceans Fishery

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

2.5.5.4 Precious Corals Fishery

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

2.6 MARINE PLANNING

2.6.1 Introduction

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

At its 165th meeting in March 2016, in Honolulu, Hawai`i, the Council approved the following objective for the FEPs: Consider the Implications of Spatial Management Arrangements in Council Decision-making. The following sub-objectives apply:

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.

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

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

2.6.1.1 Response to Previous Council Recommendations

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

2.6.1.2 MMAs established under FMPs

Council-established MMAs were compiled from 50 CFR § 665, Western Pacific Fisheries, the Federal Register, and Council amendment documents. All regulated fishing areas and large MMAs, including the PRIMNM, are shown in Figure 33.

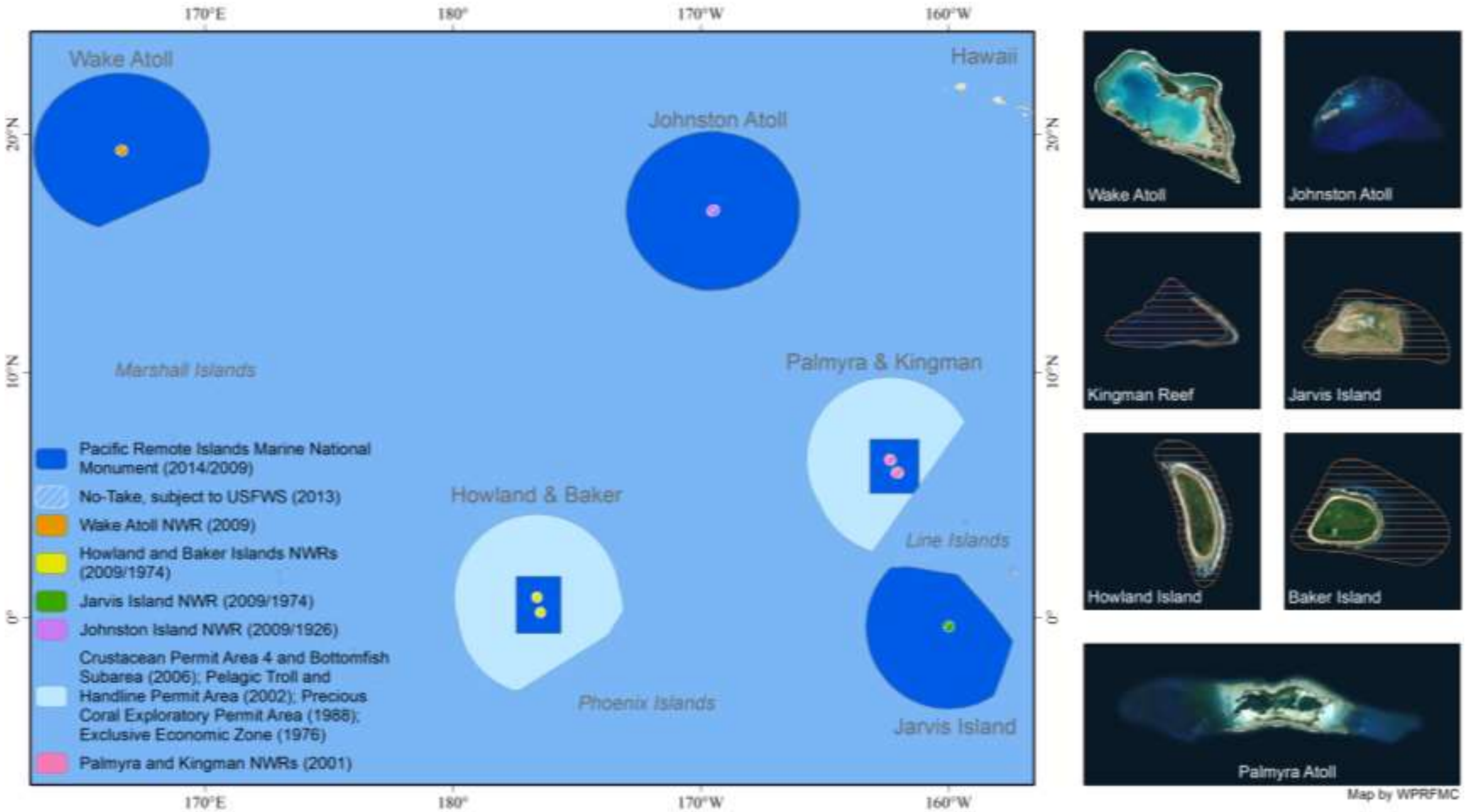

Figure 33. Regulated fishing areas of the PRIA

Table 10. 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
Howland Island No-Take MPA/PRIMNM	PRIA/ Pelagic	Howland Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem Fishery Management Plan (FMP) 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nm.	2013	-
Jarvis Island No-Take MPA/PRIMNM	PRIA/ Pelagic	Jarvis Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nm.	2013	-
Baker Island No-Take MPA/PRIMNM	PRIA/ Pelagic	Baker Island	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; commercial fishing prohibited within 12 nm.	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/PRIMNM	PRIA/ Pelagic	Kingman Reef	665.599 and 665.799(a)(1) 69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	All Take Prohibited	Minimize adverse human impacts on coral reef resources; all fishing prohibited within 12 nm.	2013	-
Johnston Atoll Low-Use MPA/ PRIMNM	PRIA/ Pelagic	Johnston Atoll	69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nm in Am. 2.	2013	-
Palmyra Atoll Low-Use MPAs/ PRIMNM	PRIA/ Pelagic	Palmyra Atoll	69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nm in Am. 2.	2013	-
Wake Island Low-Use MPA/ PRIMNM	PRIA/ Pelagic	Wake Island	69 FR 8336 Coral Reef Ecosystem FMP 78 FR 32996 PRIA FEP Am. 2	-	Special Permit Only	Minimize adverse human impacts on coral reef resources; superseded by prohibiting fishing within 12 nm in Am. 2.	2013	-

2.6.2 Activities and Facilities

There are no aquaculture facilities, alternative energy facilities, or military training and testing activities occurring in the US EEZ around the PRIA at this time. The Plan Team will add to this section as new facilities or activities are proposed and/or built.

3 DATA INTEGRATION

The purpose of this section ("Chapter 3") of the annual SAFE report is to identify and evaluate potential fishery ecosystem relationships between fishery parameters and ecosystem variables to assess how changes in the ecosystem can affect fisheries across the Western Pacific region. "Fishery ecosystem relationships" are those associations between various fishery-dependent data measures (e.g., catch, effort, or catch per unit effort), and other environmental attributes (e.g., temperature, precipitation, current velocity) that may contribute to observed trends or act as potential indicators of the status of prominent stocks in the fishery. Data integration analyses represent a first step in a sequence of exploratory analyses that will be utilized to inform new assessments of what factors may be useful going forward and were first incorporated in the 2017 versions of the annual SAFE reports.

To support the development of Chapter 3 of the annual SAFE report, staff from the Council, NMFS PIFSC and PIRO, and Triton Aquatics (consultants), held a SAFE Report Data Integration Workshop (hereafter, "the Workshop") on November 30, 2016 to identify potential fishery ecosystem relationships relevant to local policy in the Western Pacific region and determine appropriate methods to analyze them. The archipelagic fisheries group developed nearly 30 potential fishery ecosystem relationships to examine across bottomfish, coral reef, and crustacean fisheries based on data reliability, suitability of methodology, repeatability on an annual basis, and how well analyses could potentially inform management decisions (Table 11). It is important to note that these lists were developed before the ecosystem component FEP amendments were developed.

Table 11. List of brainstormed potential archipelagic island fishery relationships scored and ranked from highest to lowest priority

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

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

The data integration chapter of this report is not fully developed due to the absence of consistent fisheries data in the PRIA. The archipelagic data integration chapter is meant to explore the potential association between fishery parameters and ecologically associated variables that may be able to explain a portion of the variance in fishery-dependent data. The Workshop produced a long list of fishery and ecosystem variable combinations that comprise a significant workload that the participants could not take on without sufficient data coverage. Though a contractor completed exploratory evaluations for the MHI, Guam, CNMI, and American Samoa in 2017 for inclusion in the 2017 Annual SAFE Reports, no explicit analyses were conducted for the PRIA.

3.1 RECENT RELEVANT ABSTRACTS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Jardim E, Azevedo M, Brodziak J, Brooks EN, Johnson KF, Klibansky N, Millar CP, Minto C, Mosqueira I, Nash RD, et al. 2021. Operationalizing ensemble models for

scientific advice to fisheries management. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsab010.

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

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

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

Kasperski S, DePiper GS, Blake S, Colburn LL, Jepson M, Haynie1 AC, Karnauskas M, Leong KM, Lipton D, Masi M, et al. 2021. Assessing the State of Coupled Social-Ecological Modeling in Support of Ecosystem Based Fisheries Management in the U.S. Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.631400.

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

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

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

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

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

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

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

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

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

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

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

Timmers MA, Jury CP, Vicente J, Bahr KD, Webb MK, Toonen RJ. 2021. Biodiversity of coral reef cryptobiota shuffles but does not decline under the combined stressors of ocean warming and acidification. Proceedings of the National Academy of Sciences. Volume 118: Issue 39. https://doi.org/10.1073/pnas.2103275118.

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

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

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

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APPENDIX A: LIST OF MANAGEMENT UNIT SPECIES

The PRIA species list and Fish Stock Sustainability Index (FSSI) status will be made available in subsequent reports as resources allow. Please see the PRIA FEP and implementing regulations for the list of managed species.

APPENDIX B: LIST OF PROTECTED SPECIES AND DESIGNATED CRITICAL HABITAT

Table B-1. Protected species found or reasonably believed to be found near or in PRIA waters

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Seabirds					
Audubon's Shearwater	*Puffinus lherminieri*	Not Listed	N/A	Breeding	Sala et al. 2014
Band-Rumped Storm-Petrel	*Oceanodroma castro*	Not Listed	N/A	Visitor	Sala et al. 2014
Black Noddy	*Anous minutus*	Not Listed	N/A	Breeding	Sala et al. 2014
Black-Footed Albatross	*Phoebastria nigripes*	Not Listed	N/A	Breeding	Sala et al. 2014
Black-Naped Tern	*Sterna sumatrana*	Not Listed	N/A	Visitor	Sala et al. 2014
Black-Winged Petrel	*Pterodroma nigripennis*	Not Listed	N/A	Visitor	Sala et al. 2014
Blue-Gray Noddy	*Procelsterna cerulea*	Not Listed	N/A	Breeding	Sala et al. 2014
Bonin Petrel	*Pterodroma hypoleuca*	Not Listed	N/A	Visitor	Sala et al. 2014
Bridled Tern	*Onychoprion anaethetus*	Not Listed	N/A	Visitor	Sala et al. 2014
Brown Booby	*Sula leucogaster*	Not Listed	N/A	Breeding	Sala et al. 2014
Brown Noddy	*Anous stolidus*	Not Listed	N/A	Breeding	Sala et al. 2014
Bulwer's Petrel	*Bulweria bulwerii*	Not Listed	N/A	Breeding	Sala et al. 2014
Christmas Shearwater	*Puffinus nativitatis*	Not Listed	N/A	Breeding	Sala et al. 2014
Fairy Tern	*Sternula nereis*	Not Listed	N/A	Breeding	Sala et al. 2014
Flesh-Footed Shearwater	*Ardenna carneipes*	Not Listed	N/A	Visitor	Sala et al. 2014
Gould's Petrel	*Pterodroma leucoptera*	Not Listed	N/A	Visitor	Sala et al. 2014
Great Crested Tern	*Thalasseus bergii*	Not Listed	N/A	Visitor	Sala et al. 2014
Great Frigatebird	*Fregata minor*	Not Listed	N/A	Breeding	Sala et al. 2014
Gray-Backed Tern	*Onychoprion lunatus*	Not Listed	N/A	Breeding	Sala et al. 2014
Hawaiian Petrel	*Pterodroma sandwichensis (Pterodroma phaeopygia sandwichensis)*	Endangered	N/A	Visitor	32 FR 4001, Sala et al. 2014
Herald Petrel	*Pterodroma heraldica*	Not Listed	N/A	Visitor	Sala et al. 2014
Kermadec Petrel	*Pterodroma neglecta*	Not Listed	N/A	Visitor	Sala et al. 2014
Laysan Albatross	*Phoebastria immutabilis*	Not Listed	N/A	Breeding	Sala et al. 2014

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Lesser Frigatebird	*Fregata ariel*	Not Listed	N/A	Breeding	Sala et al. 2014
Little Shearwater	*Puffinus assimilis*	Not Listed	N/A	Visitor	Sala et al. 2014
Masked Booby	*Sula dactylatra*	Not Listed	N/A	Breeding	Sala et al. 2014
Murphy's Petrel	*Pterodroma ultima*	Not Listed	N/A	Visitor	Sala et al. 2014
Newell's Shearwater	*Puffinus newelli (Puffinus auricularis newelli)*	Threatened	N/A	Visitor	40 FR 44149, Sala et al. 2014
Phoenix Petrel	*Pterodroma alba*	Not Listed	N/A	Former breeder	Sala et al. 2014
Polynesian Storm-Petrel	*Nesofregetta fuliginosa*	Not Listed	N/A	Visitor	Sala et al. 2014
Northern Fulmar	*Fulmarus glacialis*	Not Listed	N/A	Breed and range across North Pacific Ocean.	Hatch & Nettleship 2012
Sooty Shearwater	*Ardenna grisea*	Not Listed	N/A	Breed in the southern hemisphere and migrate to the northern hemisphere.	BirdLife International 2017
Short-Tailed Albatross	*Phoebastria albatrus*	Endangered	N/A	Breed in Japan and NWHI, and range across the North Pacific Ocean.	35 FR 8495, 65 FR 46643, BirdLife International 2017
Sea turtles					
Green Sea Turtle	*Chelonia mydas*	Endangered (Central South Pacific DPS)	N/A	Occur at Wake Island and Palmyra Atoll. Few sightings around Howland, Baker, Jarvis, and Kingman reef.	43 FR 32800, 81 FR 20057, Balazs 1982
Green Sea Turtle	*Chelonia mydas*	Threatened (Central North Pacific DPS)	N/A	Forage around Johnston Atoll.	43 FR 32800, 81 FR 20057, Balazs 1985
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (North Pacific DPS)	N/A	No known sightings. Found worldwide along continental shelves, bays, estuaries, and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Dodd 1990, NMFS & USFWS 1998
Loggerhead Sea Turtle	*Caretta caretta*	Endangered (South Pacific DPS)	N/A	No known sightings. Found worldwide along continental shelves, bays, estuaries, and lagoons of tropical, subtropical, and temperate waters.	43 FR 32800, 76 FR 58868, Dodd 1990, NMFS & USFWS 1998
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened (Entire species, except for endangered	N/A	No known sightings. Occur worldwide in tropical and warm temperate ocean waters.	43 FR 32800, Pitman 1990, Balacz 1982

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
		breeding population on the Pacific coast of Mexico).			
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered[a]	N/A	No known sightings. Occur worldwide in tropical and subtropical waters.	35 FR 8491, Baillie & Groombridge 1996
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered[a]	N/A	No known sightings. Occur worldwide in tropical, subtropical, and subpolar waters.	35 FR 8491, Eckert et al. 2012
Marine mammals					
Bryde's Whale	*Balaenoptera edeni*	Not Listed	Non-strategic	Distributed widely across tropical and warm-temperate Pacific Ocean.	Leatherwood et al. 1982
Blue Whale	*Balaenoptera musculus*	Endangered	Strategic	Extremely rare. Distributed worldwide in tropical and warm-temperate waters.	35 FR 18319, McDonald et al. 2006, Stafford et al. 2001, Bradford et al. 2013, Northrop et al. 1971, Thompson & Friedl 1982
Fin Whale	*Balaenoptera physalus*	Endangered	Strategic	Found worldwide.	35 FR 18319, Hamilton et al. 2009
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Hawaii DPS)	Strategic	Breed in waters around MHI during the winter.	35 FR 18319, 81 FR 62259, Childerhouse et al. 2008, Rice & Wolman 1978, Wolman & Jurasz 1976, Herman & Antinoja 1977,
Humpback Whale	*Megaptera novaeangliae*	Delisted Due to Recovery (Oceania DPS)	Strategic	Breed in Oceania waters during the winter.	35 FR 18319, 81 FR 62259, Guarrige et al. 2007, SPWRC 2008
Humpback Whale	*Megaptera novaeangliae*	Endangered (Western North Pacific DPS)	Strategic	Small population of about 1,000 that breeds in Asian waters during the winter.	35 FR 18319, 81 FR 62259, Eldredge et al. 2003; Barlow et al. 2011; Calambokidis et al. 2001, 2008
Sei Whale	*Balaenoptera borealis*	Endangered	Strategic	Generally found in offshore temperate waters.	35 FR 18319, Barlow 2003, Bradford et al. 2013

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Non-strategic	Distributed worldwide in tropical and warm-temperate waters.	Perrin et al. 2009
False Killer Whale	*Pseudorca crassidens*	Not Listed	Non-strategic	Two stocks found in or near PRIA waters: 1) Palmyra Atoll stock found within US EEZ waters around Palmyra Atoll, and 2) Hawaii pelagic stock which includes animals in waters more than 40 km from the MHI. Little known about these stocks. Found worldwide in tropical and warm-temperate waters.	Barlow et al. 2008, Bradford & Forney 2013, Stacey et al. 1994, Chivers et al. 2010
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide.	Ross & Leatherwood 1994
Risso's Dolphin	*Grampus griseus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin et al. 2009
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide.	Perrin et al. 2009
Common Dolphin	*Delphinus delphis*	Not Listed	Non-strategic	Found worldwide in temperate and subtropical seas.	Perrin et al. 2009
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters worldwide. Found in waters around Johnston and Palmyra Atolls.	Shallenberger 1981, Baird et al. 2013, Bradford et al. 2013
Spinner Dolphin	*Stenella longirostris*	Not Listed	Non-strategic	Found worldwide in tropical and warm-temperate waters. Occur in shallow protected bays during the day, feed offshore at night.	Norris and Dohl 1980, Norris et al. 1994, Hill et al. 2010, Andews et al. 2010, Karczmarski 2005, Perrin et al. 2009
Spotted Dolphin	*Stenella attenuata*	Not Listed	Non-strategic	Found in tropical and subtropical waters worldwide. Sighted in waters around Palmyra and Johnston atolls.	Perrin et al. 2009, NMFS PIR unpub. Data
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Non-strategic	Found in tropical to warm-temperate waters throughout the world.	Perrin et al. 2009

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
Guadalupe Fur Seal	*Arctocephalus townsendi*	Threatened	Strategic	No known sightings. Little known about their pelagic distribution. Breed mainly on Isla Guadalupe, Mexico.	50 FR 51252, Gallo-Reynoso et al. 2008, Fleischer 1987
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered[a]	Strategic	Endemic tropical seal. Occurs throughout the Hawaiian archipelago. Occasional sightings on Johnston atoll.	41 FR 51611, Antonelis et al. 2006
Northern Elephant Seal	*Mirounga angustirostris*	Not Listed	Non-strategic	Females migrate to central North Pacific to feed on pelagic prey.	Le Beouf et al. 2000
Sperm Whale	*Physeter macrocephalus*	Endangered	Strategic	Found in tropical to polar waters worldwide, most abundant cetaceans in the region.	35 FR 18319, Rice 1960, Lee 1993, Barlow 2006, Mobley et al. 2000, Shallenberger 1981
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Non-strategic	Found worldwide in tropical and temperate waters.	Mead 1989
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Non-strategic	Occur worldwide.	Heyning 1989
Sharks					
Giant manta ray	*Manta birostris*	Threatened	N/A	Found worldwide in tropical, subtropical, and temperate waters. Commonly found in upwelling zones, oceanic island groups, offshore pinnacles and seamounts, and on shallow reefs.	Dewar et al. 2008, Marshall et al. 2009, Marshall et al. 2011.
Oceanic whitetip	*Carcharhinus longimanus*	Threatened	N/A	Found worldwide in open ocean waters from the surface to 152 m depth. It is most commonly found in waters > 20°C	Bonfil et al. 2008, Backus et al, 1956, Strasburg 1958, Compagno 1984
Scalloped hammerhead	*Sphyrna lewini*	Endangered (Eastern Pacific DPS)	N/A	Found in coastal areas from southern California to Peru.	Compagno 1984, Baum et al. 2007, Bester 2011
Scalloped hammerhead	*Sphyrna lewini*	Threatened (Indo-West Pacific DPS)	N/A	Occur over continental and insular shelves, and adjacent deep waters, but rarely found in waters < 22°C. Range from the intertidal and surface to depths up to 450–512 m.	Compagno 1984, Schulze-Haugen & Kohler 2003, Sanches 1991, Klimley 1993
Corals					

Common Name	Scientific Name	ESA Listing Status	MMPA Status	Occurrence	References
N/A	*Acropora globiceps*	Threatened	N/A	Occur on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 m	Veron 2014
N/A	*Acropora retusa*	Threatened	N/A	Occur in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and depth range is 1 to 5 m.	Veron 2014
N/A	*Acropora speciosa*	Threatened	N/A	Found in protected environments with clear water and high diversity of Acropora and steep slopes or deep, shaded waters. Depth range is 12 to 40 meters and have been found in mesophotic habitat (40-150 m).	Veron 2014

[a] These species have critical habitat designated under the ESA. See Table B-2.

Table B-2. ESA-listed species' critical habitat in the Pacific Ocean[a].

Common Name	Scientific Name	ESA Listing Status	Critical Habitat	References
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	None in the Pacific Ocean.	63 FR 46693
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Approximately 16,910 square miles (43,798 square km) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meter depth contour; and 25,004 square miles (64,760 square km) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.	77 FR 4170
Hawaiian Monk Seal	*Neomonachus schauinslandi*	Endangered	Ten areas in the Northwestern Hawaiian Islands (NWHI) and six in the main Hawaiian Islands (MHI). These areas contain one or a combination of habitat types: Preferred pupping and nursing areas, significant haul-out areas, and/or marine foraging areas, that will support conservation for the species.	53 FR 18988, 51 FR 16047, 80 FR 50925
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Two specific areas are designated, one in the Gulf of Alaska and another in the Bering Sea, comprising a total of approximately 95,200 square kilometers (36,750 square miles) of marine habitat.	73 FR 19000, 71 FR 38277

[a] For maps of critical habitat, see http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm.

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